USACE CONTRACT NO. DACW33-94-D-0002
TASK ORDER NO. 017
TOTAL ENVIRONMENTAL RESTORATION CONTRACT

FINAL
PRE-DESIGN FIELD TEST
DREDGE TECHNOLOGY
EVALUATION REPORT
NEW BEDFORD HARBOR SUPERFUND SITE
New Bedford, Massachusetts

August 2001

Prepared for

U.S. Army Corps of Engineers
New England District
Concord, Massachusetts

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Prepared by

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ABBREVIATIONS AND ACRONYMS

alum	aluminum sulfate
BARR.PR	Barometric Pressure, inches of Hg
BATTERY	Meteorological Station Battery Voltage
Bean TEC	Bean Technical Excavation Corporation
BELLC	Bean Environmental LLC
CDF	confined disposal facility
cf	cubic feet
CGI	Combustible/Toxic Gas Indicator
CMS	Crane Monitoring System
CO_2	Carbon Dioxide
CRZ	Contaminant Reduction Zone
cy	cubic yards
cy/hr	cubic yards per hour
DDA	debris disposal area
DELTA-T	Temperature Differences
DEP	Massachusetts Department of Environmental Protection
DGPS	Differential Global Positioning System
DTM	Digital Terrain Model
ECD	electron capture detector
EE/O	electrical energy per order
EHS	Environmental, Health & Safety
ENSR	ENSR International
EPA	U.S. Environmental Protection Agency
EZ	Exclusion Zone
ft.	feet
ft^2	square feet
FWENC	Foster Wheeler Environmental Corporation
g/L	grams per liter
GAC	granulated activated carbon
GC	gas chromatography
gpm	gallons per minute
H_2S	Hydrogen Sulfide
HDPE	high density polyethylene
HPG	Horizontal Profiling Grab bucket
in.	inches
Kg/m^3	kilograms per $meter^3$
kW	kilowatt
lbs	pounds
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MHW	Mean High Water
MLLW	Mean Lower Low Water
mm	millimeter
MRL	method reporting limit
MS	mass spectrometry
NBH	New Bedford Harbor
ng/m^2-min	nanogram per $meter^2$ minute
NOAA	National Oceanographic and Atmospheric Administration
NTU	Nephelometric Turbidity Units

OBS	optical backscatter sensor
PCB	polychlorinated biphenyl
pcf	pounds per cubic foot
PDFT	Pre-Design Field Test
PID	Photo-Ionization Detector
PPE	personal protective equipment
ppm	parts per million
PRECIP	Precipitation, inches
psig	pounds per square inch gauge
RH	Relative Humidity, %
RL	Reporting Limit
ROD	Record of Decision
RPD	Relative Percent Difference
RTK	Real Time Kinematic
SAP	Sampling and Analysis Plan
SG	specific gravity
SGU	specific gravity unit
SIGMA	Standard Deviation, degrees
SIM	selected ion monitoring
SPU	Slurry Processing Unit
SR	Solar Radiation, watts $\cdot$ m^2
SSHP	Site Safety and Health Program
TEMP10M	Temperature (°F) at 10 meters aboveground surface
TEMP2M	Temperature (°F) at 2 meters aboveground surface
TSS	total suspended solids
µg/L	micrograms per liter
USACE	U.S. Army Corps of Engineers, New England District
WD	Wind Direction, degrees
WES	Waterways Experiment Station
WHO	World Health Organization
WS	Wind Speed, miles per hour
WTP	Wastewater Treatment Plant

ABSTRACT

The New Bedford Harbor Superfund Site is contaminated with polychlorinated biphenyls (PCBs), heavy metals and other chemicals. Remediation of the site will include dredging contaminated sediments from the harbor to final placement in shoreline confined disposal facilities (CDFs).

This report focuses on the dredging component of the remedial design and presents results of the August 2000, Pre-Design Field Test (PDFT). The main objective of this PDFT was to determine site specific dredge performance values for use in developing a full-scale remediation plan. The PDFT demonstrated and recorded performance data including dredge production, accuracy, slurry solids concentration, and air and water quality impacts.

Foster Wheeler Environmental Corporation subcontracted with Bean Environmental LLC for the delivery and demonstration of a hybrid environmental mechanical/hydraulic excavator dredge. The hybrid dredge was designed to enable accurate dredging of the contaminated sediment, minimize the amount of water added during the slurry pumping process by recycling water decanted from the slurry effluent, and minimize the potential for adverse environmental impacts. The dredging system delivered to the site for the PDFT included a portable, shallow draft barge platform, a Horizontal Profiling Grab bucket (HPG), a Crane Monitoring System (CMS), the Bean patented Slurry Processing Unit (SPU), and a water recirculation system.

Dredge Production

Dredging was performed to obtain representative production rates over a range of conditions, including varying depths, bank height, and chemical and physical conditions. Production monitoring data were collected using a number of electronic data collectors and were summarized daily.

Over the course of the PDFT, the representative average production rate for the dredge was 80 cubic yards per hour (cy/hr). It is believed that excavator production could be increased by 20% on a full-scale project in the Upper Harbor to approximately 95 cy/hr with system optimization.

Dredging Accuracy

The test dredge equipment demonstrated that a mechanical bucket, operated from an excavator with rigid connections and a state-of-the-art monitoring and positioning system could achieve a +/- 4-inch vertical dredging accuracy based on comparison of the PDFT post-dredge survey with the target depths. An accuracy evaluation showed that 95% of the test area was dredged to within 6 inches (in.) of the target depth, and 90% of the test area was dredged to within 4 in.

Another component of the dredging accuracy evaluation was development and testing of a “visual” method to determine dredging depth. The visual method provides a fine-tuning of the dredge plan based on the continuous observations of the “clean” underlying clay layer. The goal of the visual method is to minimize removal of the underlying clay layer to eliminate unnecessary dredging, and further costly processing and storage.

Solids Concentration of Dredge Slurry

Average solids concentration values recorded by the SPU system over sustained dredging periods ranged from 13.3% to 16.3% solids by weight. These concentrations were achieved in dredge areas having *in situ* sediments with average solids concentrations of 32% to 43% solids by weight.

The use of the SPU system on the cleanup of the Upper and Lower Harbors, could reduce the volume of water transported and treated by an estimated 50% to 70% below that required for a hydraulic cutterhead system.

Recirculation System

A water recirculation system was integrated with the test dredge to evaluate the feasibility of recycling water generated by the hydraulic transport process. The recirculation system was highly effective in essentially creating a closed loop system, whereby the only water added to the dredge process was that entrained in the dredge bucket. Without the recirculation system, the volume of water added would be approximately 320% of the *in situ* volume. The recirculation system operated without any significant problems, and confirmed the feasibility of using such a system on the full-scale remediation.

PCB Removal Efficiency

A secondary objective of the PDFT was to evaluate this new dredging technology with regard to site specific cleanup levels. The dredge performed quite well in this regard. The average sediment PCB concentration (upper one foot) was reduced from 857 ppm to 29 ppm over the dredged area. This met the clean up criteria of 50 ppm for the Lower Harbor and approached the criteria of 10 ppm for the Upper Harbor. Based on experiences during the PDFT, it was determined that remedial dredging to 10 ppm is possible through the use of modified operational procedures and project design.

Water Quality Monitoring

Water quality monitoring revealed only a very limited impact on the water column from the actual dredging in terms of both PCBs and suspended solids. The detected elevations of these parameters were within the range of fluctuations normally found in the Harbor with changing environmental conditions. This limited impact was attributed to the bucket design and the method of operation. Larger increases in water column suspended solids and PCB concentrations were attributed to dredging support activities.

Air Quality Monitoring

Flux chamber samples and ambient air samples were collected to achieve various objectives during the PDFT. Overall, this air sampling indicated that CDFs will be a more significant PCB emissions source than the dredging platform.

Wastewater Treatment

Results of the wastewater treatment pilot study showed that granular activated carbon when used with clarification and filtration can remove PCB concentrations to below the site-specific discharge limit of 0.065 milligrams per liter (mg/L) per Aroclor. The study also showed that sludge generated from wastewater treatment plant operations could be dewatered using a plate and frame filter press.

Comparison with Baseline Dredge Technology

A comparison was made between the key performance areas evaluated during the 1989 Pilot Dredging, 1995 Hot Spot Dredging and 2000 PDFT events. The Ellicott 370 HP 10-inch hydraulic cutterhead dredge was the established baseline dredge in terms of dredging performance in the former two events. The PDFT demonstrated that current state-of-the-art dredge technology, in particular a hybrid mechanical/hydraulic dredge with sophisticated environmental controls systems, can attain dredge performance values exceeding that of the baseline dredge, particularly in the areas of dredging accuracy, dredging production, and solids concentration of the dredge slurry.

EXECUTIVE SUMMARY

INTRODUCTION

The New Bedford Harbor Superfund Site is contaminated with polychlorinated biphenyls (PCBs), heavy metals and other chemicals. Remediation of the site will be conducted in accordance with the Record of Decision (ROD) dated September 25, 1998 which includes dredging contaminated sediments from the harbor to final placement in shoreline confined disposal facilities (CDFs).

This report focuses on the dredging component of the remedial design and presents results of the August 2000, Pre-Design Field Test (PDFT) conducted to determine site specific dredge performance values for use in developing a full-scale remediation plan. Dredge performance values were previously estimated based on results of conventional and alternative hydraulic dredging systems used at the site in 1989 for a Pilot Dredging Study, and in 1995 for Hot Spot dredging. However, changes in dredge technology over the past several years makes it likely that newer technology could improve dredge production and other performance values over previous estimates. The PDFT demonstrated and recorded performance data including dredge production, accuracy, slurry solids concentration, and air and water quality impacts. To reflect full-scale remediation activities to the greatest extent possible, the PDFT was conducted over a 100-feet (ft.) by 550-ft. area in the New Bedford Upper Harbor. The PDFT team included: the U.S. Environmental Protection Agency - Region I, the U.S. Environmental Protection Agency (EPA), Narragansett, RI, Atlantic Ecology Division of the National Health and Environmental Effects Laboratory, the U.S. Army Corps of Engineers, New England District (USACE), the Massachusetts Department of Environmental Protection (DEP), Foster Wheeler Environmental Corporation (Foster Wheeler), Bean Environmental LLC (BELLC), ENSR International (ENSR), URS, Kevric, and CR Environmental.

OBJECTIVES

To evaluate the performance improvements of a state-of-the-art environmental dredge technology over conventional dredge technology previously used at the site several performance areas were evaluated:

- Horizontal and vertical dredging;
- Potential impacts to water quality;
- Potential impacts to air quality;
- Dredge production rates in shallow water and sediment with debris;
- Percent (%) solids concentrations in the dredge slurry and slurry pumping capabilities; and
- Removal of the contaminated sediment to a given depth.

A secondary objective of the PDFT was to evaluate this new technology with regard to site specific cleanup levels. Additional objectives of the PDFT were to evaluate the effectiveness of applying contaminant dispersants and flocculents within the CDF to reduce PCB losses to air, to evaluate mechanical dewatering methods and to evaluate the use of granulated activated carbon (GAC) to treat wastewater.

DREDGING TEST PLAN

The dredging test plan consisted of dredge technology selection, dredge performance tests, water quality monitoring, air quality monitoring, and wastewater treatment. A testing schedule was established to ensure that dredge performance testing and monitoring would be captured over five to ten days of dredging. In total, four days (from August 10, 2000 through August 13, 2000) were spent performing trial dredging during which the dredge system underwent modifications to prepare for test dredging. Test dredging was performed over the course of five days (from August 14, 2000 through August 18, 2000).

DREDGE TECHNOLOGY SELECTION

Over sixty dredge technologies available in the United States and internationally were screened prior to selecting three technologies demonstrating the highest probability for success in meeting the New Bedford Harbor project constraints. The technologies selected were:

- The Bean Technical Excavation Corporation (Bean TEC) Bonacavor
- The Normrock Industries *Amphibex*
- The Ellicott International Series 370 hydraulic cutterhead dredge

Because the Normrock Industries *Amphibex* was at the time built on a foreign hull and prohibited from operating in navigable waters of the U.S. under the Jones Act, and because adequate performance data was already available for the Ellicott 370 hydraulic cutterhead dredge, the PDFT only evaluated the Bean type environmental hydraulic excavator.

Foster Wheeler subcontracted with BELLC for the delivery and demonstration of a hybrid environmental mechanical/hydraulic excavator to work along with the Slurry Processing Unit (SPU) previously patented by C.F. Bean Corporation, now C.F. Bean LLC, an affiliate of BELLC. The hybrid dredge was designed to enable accurate dredging of the contaminated sediment, minimize the amount of water added during the slurry pumping process, and recycle the dredge slurry effluent. The dredging system delivered to the site for the PDFT included a portable, shallow draft barge platform, a Horizontal Profiling Grab bucket (HPG), a Crane Monitoring System (CMS), the Bean patented SPU, and a water recirculation system. The main components of the system are described in more detail below.

Horizontal Profiling Grab Bucket (HPG)

A HPG was used by BELLC to achieve the PDFT goal of applying mechanical dredging equipment to the site. The HPG is a mechanical clamshell bucket developed in the Netherlands, designed to excavate thin layers of material with a high degree of accuracy causing minimal spill and turbidity. A hydraulic excavator (backhoe) operates the HPG bucket, with rigid connections rather than wire cable, which are used with a conventional crane derrick. Since the HPG bucket is actively closed by hydraulic cylinders, instead of closing wires, its vulnerability to debris is also significantly reduced. The HPG was designed to provide a level cut as opposed to a conventional clamshell bucket's semi-circular or arched cut which decreases the need for overlap between adjacent grabs to achieve grade. The HPG is also designed to minimize resuspension of sediments by containing the dredged material during excavation and placement.

Crane Monitoring System (CMS)

The CMS is an on-board electronic sensor system that provides the dredge operator precise control of the bucket while dredging, both in the horizontal and vertical planes, and interprets signals from various components of the dredging system onto a computer display. The design dredge prism is based on the interpretation of the core logs by the design team. In using the CMS, the operator dredges in pre-programmed dredge sets based on a planned horizontal and vertical grid.

Slurry Processing Unit (SPU)

To minimize the amount of water delivered to the CDFs, the Bean patented SPU, which has been used successfully on other remediation projects to achieve high solids concentrations in the dredge slurry, was tested during the PDFT. The SPU system is a proprietary hydraulic slurry transport system that delivers high percent solids concentrations by introducing controlled amounts of water to mechanically dredged material.

Recirculation System

The SPU system is intended to minimize the amount of water added to the dredged material such that the dredge slurry density is optimized. Due to the full-scale project parameters and anticipated water requirements, additional efforts were made to develop a system that would serve to further minimize the volume of water generated during the full-scale project; therefore, a water recirculation system was also tested in the PDFT. The recirculation system involved the pumping of decant water from the CDF back to the dredge for use as make-up water, thereby creating a closed loop system.

DREDGE PERFORMANCE TESTS

The dredge performance tests evaluated three areas:

1) Dredge performance at removing PCBs:
    - Dredge production over a range of conditions
    - Dredging accuracy
    - Solids concentration of the dredge slurry
    - Recirculation system effectiveness
    - PCB removal efficiency (before and after sediment sampling).

2) Water Quality impacts within the Upper Harbor caused by dredging operations.

3) Air Quality impacts at the point of dredging and at the Sawyer Street CDF.

Dredge Production

Dredge production monitoring was performed during dredging operations in the PDFT test area. Dredging was performed to obtain representative production rates over a range of conditions, including varying depths, bank height, and chemical and physical conditions. Production monitoring data were collected using a number of electronic data collectors and were summarized daily. Excavator production and SPU production affected the overall dredge production. Excavator production was found to be dependent upon basic dredge production parameters including bucket capacity, cycle time, depth of cut, bank height, and dredge shifting (advances). Over the course of the PDFT, the representative average production rate for the excavator was 80 cubic yards per hour (cy/hr) in areas with bank height ranging between 1.7 ft. and 2.0 ft. It is believed that excavator production could be increased by 20% on a full-scale project in the Upper Harbor to approximately 95 cy/hr if the system is optimized. This production range would only be attainable in deeper areas of the harbor where access to the dredge areas would be unencumbered by a dredge of similar scale, and draft characteristics to that tested during the PDFT. In shallower areas, where working of the tides would increase the number of barge movements and reduce the overall dredging efficiency, the dredge production would be anticipated to be significantly less. Alternatively, a smaller dredge with less production capacity than that of a dredge of the scale tested during the PDFT could be used. In either case, with either a larger dredge working the tides, or with use of a smaller dredge, the production range would be on the order of 35 to 50 cy/hr. This is an estimate only, based on knowledge of the anticipated reduction in production efficiency (50%-60%) due to depth restriction on a larger dredge, and an understanding of production capacity of shallow hydraulic dredges. Both the breakpoint at which a larger production environmental dredge would be replaced by a smaller dredge, and the production range of that smaller dredge will be better assessed in the 90% Basis of Design/Design Analysis for the Dredging Design, to be completed in 2001.

SPU production was found to be the dredge production limit in testing during the PDFT, due primarily to problems with debris clogging. Attempts were made during the PDFT to remedy clogging problems by adding water jets in the suction line, welding baffle walls in the hopper, and other operational measures. It is believed that by optimizing the debris management system, SPU production will match, or exceed that of the excavator production for full-scale remediation.

Dredging Accuracy

Dredging accuracy will be key to minimizing the amount of overdredging while still attaining the target cleanup goals of the project. The test dredge equipment demonstrated that a mechanical bucket, operated from an excavator with rigid connections and a state-of-the-art monitoring and positioning system could achieve a +/- 4 inch vertical dredging accuracy based on comparison of the PDFT post-dredge survey with the target depths. An accuracy evaluation showed that 95% of the test area was dredged to within 6 inches (in.) of the target depth, and 90% of the test area was dredged to within 4 in. Most of the points that deviate more than 6 in. are in the slope area, to the north and south of the test area.

Another component of the dredging accuracy evaluation was development and testing of a "visual" method to determine dredging depth. The visual method provided a fine-tuning of the dredge plan based on the continuous observations of the "clean" underlying clay layer. Laboratory analysis has shown the clay layer to contain little to no PCB contamination, and is therefore assumed clean. The goal of the visual method is to minimize removal of the underlying clay layer to eliminate unnecessary dredging, and further costly processing and storage. In locations where this method was used, the depth of cut was reduced from a planned 2-ft. cut, to a 1.7-ft. and 1.8-ft. cut. The visual method was demonstrated as having potential for application across the New Bedford Harbor dredge areas where a distinct interface between the black organic silt surface layer and underlying, native clean gray clay layer is present.

Solids Concentration of Dredge Slurry

Average sustained solids concentration values recorded by the SPU system over sustained dredging periods ranged from 13.3% to 16.3% solids by weight. These concentrations were achieved in dredge areas having *in situ* sediments with average solids concentrations of 32% to 43% solids by weight. This corresponds to volume concentrations on the order of 40% to 50%. The solids concentration values attained by the BELLC dredge were affected by debris clogging. Higher solids concentrations would be attainable with inclusion of a more sophisticated debris separation system on the full-scale project.

The use of the SPU system on the cleanup of the Upper and Lower Harbors could reduce the volume of water transported and treated by an estimated 50% to 70% below that required for a hydraulic cutterhead system. A specific range of slurry density could be prescribed and provided by the SPU that would best accommodate the decanting time, recirculation water pressure, and movement of dredge material disposal operations within the CDF's.

Recirculation System

A water recirculation system was integrated with the test dredge to evaluate the feasibility of recycling water generated by the hydraulic transport process. The recirculation system was highly effective in essentially creating a closed loop system, whereby the only water added to the dredge process was that entrained in the dredge bucket. This water addition amounts to approximately 40% of the *in situ* volume. The water was recycled back to the dredge for use as make up water for the SPU system and as jet water for debris dislodgment in the suction line. As controlled by the SPU, excess recirculation water was directed back to the hopper, from the discharge line, to decrease water content and increase the solids concentration of the dredge slurry. The recirculation system operated without any significant problems, and confirmed the feasibility of using such a system on the full-scale remediation.

PCB Removal Efficiency

The evaluation of the dredge efficiency at PCB removal included two components. The first (primary) goal was to evaluate the dredge's ability to remove contaminated sediment <u>to a given depth horizon</u> relative to the dredging plan. The dredge performance was highly accurate in this regard. Comparison of the target dredge volume with the actual volume dredged yielded an overdredging value of only 16%, with vertical accuracy of +/- 4 in. relative to achieving the intended horizon. Comparison on pre- and post-dredging sediment PCB concentrations revealed that 97% of the PCB mass was removed over the dredged area.

A secondary objective of the PDFT was to evaluate this new dredging technology with regard to site specific cleanup levels. The design included: 1) delineating the 10 ppm PCB concentration horizon within the test area; 2) establishing a dredging plan based on that depth; and 3) assessing the dredge's ability to remove sediment to that depth. It should be understood that the project goal was <u>**not**</u> to leave a final sediment concentration of 10 ppm (as an average concentration over the upper one foot); this was a field test, <u>**not**</u> a remedial operation. The dredge performed quite well in this regard. The average sediment PCB concentration (upper one foot) was reduced from 857 ppm to 29 ppm over the dredged area. This met the clean up criteria of 50 ppm for the Lower Harbor and approached the criteria of 10 ppm for the Upper Harbor. A similar reduction in sediment concentration was observed for the area dredged to planned depth and the area dredged to depth based on the visual method.

The PCB mass remaining after dredging appeared to reside entirely in a thin surface veneer and was attributed to recontamination of the dredged area rather than incomplete removal. Potential recontamination mechanisms include material sloughing down slope along the sides of a dredged cut, material mobilized during bucket impact and retrieval, material mobilized during anchor wire/spud repositioning, material mobilized during support vessel operations, and general transport related to tides and meteorological events. Adjustments to dredging and operational controls will reduce the influence of many of these mechanisms, and, therefore, a corresponding reduction in surficial sediment recontamination is expected during full-scale dredging.

Based on experiences during the PDFT, it was determined that remedial dredging to 10 ppm is possible through the use of modified operational procedures and project design. During full scale operations, development of a dredge plan and sequencing that proceeds from upslope to downslope and with an understanding of the site current (tidal) regime would be made to address some of the recontamination effects due to sloughing. Additionally, dredging operational approaches could be employed during the full scale project including return sweeps, tighter overlap of bucket grabs, and slower retrieval of final bucket grab that would provide for a cleaner bottom surface and reduce sloughing of adjacent areas. As confirmation sampling results became available they would be shared with the dredge contractor and the operator in particular to modify dredging techniques to obtain a bottom that met the cleanup criteria.

Water Quality Monitoring

The test dredge's ability to minimize environmental impact to water quality by measuring the extent of contaminated sediment resuspension and transport was evaluated by ENSR, and represented a joint effort by EPA, USACE, and ENSR.

To evaluate water quality impacts associated with the PDFT, the following investigations were made:

- Predictive modeling to aid in designing the water quality monitoring field program and to assess the utility of modeling for the full-scale remediation effort. In addition, the expected suspended sediment concentration resulting from dredging activities under a variety of transport assumptions was predicted; and

- Field monitoring to assess sediment resuspension during the dredging operation, to collect water samples for laboratory analysis and to ground-truth the predictive modeling. The objectives of field monitoring included real-time location and mapping of any turbidity plume associated with the dredging as well as collection of water samples at designated stations downstream of the dredge for laboratory analysis. The monitoring program was structured to document water column conditions in the Upper Harbor over the course of ebb and flood tidal events during dredging operations. Water samples were analyzed for total suspended solids (TSS) and dissolved and particulate PCBs. An assessment of the correlation of the field turbidity and laboratory TSS data as well as the laboratory TSS and PCB data was also performed.

Correlation assessment between the field and laboratory data was made. Water quality monitoring provided data over a range of operational and environmental conditions. Upon examination of the data, it can be concluded that:

- The actual dredging process (removal of sediments with the hydraulic excavator) appeared to have a limited impact on the water column;

- Activities performed in support of dredging (operation of support vessels) appeared to have a much greater impact on water quality than the dredging; and

- Normal fluctuations in water quality occur in the Upper Harbor related to changing environmental conditions that appear similar or greater in scale than the overall impacts related to the dredging operation.

Air Sampling and Analysis

Flux chamber samples and ambient air samples were collected to achieve various objectives during the PDFT. Flux chamber sampling provided a measure of emissions as an indication of the relative contributions from the various operations to the ambient air concentrations. These will also be used to support the emissions and dispersion modeling calculations performed as part of developing ambient air action levels for upcoming construction work. In addition to flux chamber samples collected in the field, sediment from the bench scale dewatering studies was tested at the USACE Waterways Experiment Station (WES) for emissions measurements.

PDFT flux chamber sampling provided useful data for evaluating relative emissions from various sources. Some key findings are summarized as follows:

- Emission flux measurements do not correlate well with source material concentrations. However, they do generally appear to be the highest in association with well-mixed sediment and water slurries in the CDF.
- *In situ* sediments in the mudflat area do not provide the same magnitude of emission flux per square area as well mixed sediment in the CDF. However, given the large surface area of the exposed mudflats at low tide, these areas and exposed surface water will continue to be a significant source of ambient air concentrations of PCBs, as measured during the Baseline study.
- Total emissions, calculated as (flux) x (surface area) x (time), are directly proportional to the amount of exposed surface area. Accordingly, exposed CDF surface area is a significantly greater source of emissions than dredging operations. The contaminated sediments in the mudflat areas and the river/harbor surface water remain the largest surface area sources of emissions.
- Dredging activities, including the grizzly, hopper, and disturbed sediments in the moon pool are relatively small sources of PCB emissions in comparison with the CDF because of their lower flux measurements and limited surface area.
- The use of surfactants Dawn and Biosolve to control the sheen at the CDF does not appear to be effective at controlling PCB emissions. These limited data suggest that Simple Green may be more effective than other surfactants although additional testing is recommended before drawing definitive conclusions.
- The silt curtain at the moon pool appears to be somewhat effective at containing disturbed sediment thereby reducing the surface area of higher concentration water and the associated emissions in the dredge area.

Ambient air samples were collected to document conditions during dredging and CDF filling operations. The results from this study will be used in conjunction with the flux chamber results to support development of ambient air action levels, being conducted by Foster Wheeler under a separate task.

Wastewater Treatment

Dredging operations conducted as part of the PDFT resulted in generating wastewater requiring treatment before final discharge to the harbor. The volume of wastewater generated during the PDFT was minimized by the use of the water recirculation system. In an effort to test the performance of the equipment and processes proposed for a full-scale wastewater treatment system, a pilot-scale wastewater treatment system was used to treat the wastewater generated during the PDFT. Construction of the pilot-scale system was conducted from August 3, 2000 through September 3, 2000. The system was operated from September 4, 2000 through October 13, 2000 to treat over 1-million gallons of wastewater. The objectives of the pilot-scale study treatment were to evaluate the treatment efficiency, flexibility and reliability of the individual unit operations/processes and confirm the findings of the wastewater treatability studies. The individual unit operations that were evaluated in the pilot-scale treatment included:

- Chemical addition and settling;
- Ultrafine (0.45 µm nominal) sand filtration;
- Granular activated carbon adsorption;

- UV/Oxidation; and
- Sludge dewatering with a plate and frame filter press.

Water samples were collected before and after each of the unit processes. These grab samples were analyzed for TSS, PCBs, and total and dissolved metals (cadmium, chromium, copper and lead). TSS data did not indicate substantial removal of suspended solids from any of the treatment processes. Further investigation indicated some difficulty with laboratory analysis for TSS due to elevated levels of salts present in the samples. For this reason, field turbidity measurements (as NTUs) were taken to be a more accurate indicator of suspended solids removal throughout pilot-scale treatment.

Analysis results also indicate that the contaminants present within the wastewater are strongly associated with the suspended particles and by removing these suspended solids the majority of the contaminants can be removed from the wastewater stream. However, due to the source of the wastewater (seawater) there are colloidal particles present which flocculation, clarification and filtration alone cannot remove. The concentration of PCBs and copper associated with these colloidal particles is sufficient enough that the wastewater could exceed the discharge limits unless tertiary treatment in the form of activated carbon is performed.

The dewatering component of the wastewater treatment pilot-scale study showed that dewatering can reduce the water content and volume of sludge generated during the wastewater treatment process. Sludge is generated during the clarification stage and the amount of sludge generated will depend upon chemical condition, wastewater flowrates, and system operating hours.

Comparison with Baseline Dredge Technology

The Ellicott 370 HP Dragon Series 10-inch (discharge) hydraulic cutterhead dredge, used on both the Pilot Dredging Study in 1989 and the Hot Spot Dredging event in 1995 had been established as the baseline for the Upper Harbor site in terms of dredge efficiency and performance. Prior studies had excluded mechanical dredging techniques for use on these two events due primarily to the inefficiency of barge transport to the disposal facility because of shallow operating depths, the perception that a hydraulic system left a more uniform bottom surface and concern over resuspension of contaminated sediments. Comparison was made of the key performance areas evaluated during the Pilot Dredging, Hot Spot Dredging and PDFT events. The three dredging performance evaluations were conducted across different test areas with different chemical and physical conditions and with different performance testing/cleanup objectives. The PDFT, however, has demonstrated that current state-of-the-art dredge technology, in particular a hybrid mechanical/hydraulic dredge with sophisticated environmental controls systems, can attain dredge performance values exceeding that of the baseline dredge, particularly in the areas of dredging accuracy, dredging production, and solids concentration of the dredge slurry. In terms of impacts to the environment, for both the baseline dredge technology (hydraulic cutterhead) and the PDFT state-of-the art test dredge, water quality was found to be impacted by support vessels and anchor movements more so than the dredging operation itself, and air quality was found to be impacted more at the CDF than at the point of dredging.

CONCLUSIONS

A state-of-the-art hybrid mechanical/hydraulic dredging system demonstrated dredge performance values exceeding that which have previously been achieved at the New Bedford Harbor site in the areas of dredge production, accuracy, and slurry solids concentrations. Both the sediment removal data and PCB data acquired indicate that the dredging technology used for the PDFT is very efficient and has a high probability of achieving sediment PCB clean-up goals established for Upper New Bedford Harbor. Furthermore, given the data set collected during this study, the question of residual contamination due to sloughing or migration should be able to be addressed logistically by modifying certain dredging procedures during a full-scale remediation. For full-scale remediation activities, the following dredge performance design values are recommended:

Dredge Performance Parameter	Recommended Design Value
Dredging Production, Water Depths greater than 4 ft. [1]	95 cy/hr
Dredging Production, Water Depths between 2 ft. and 4 ft. [1]	35 cy/hr
Dredging Accuracy, Vertical Plane, to Design Depth	+/- .4 ft
Dredging Accuracy, Vertical Plane, using Visual Approach	+/- .5 ft
Dredging Accuracy, Horizontal	+/- 1.5 ft
Average Solids Concentration of Dredge Slurry [2]	10% - 20% solids by weight
Use of Recirculation System for reuse of Dredge Effluent Water from CDF	Recommended

[1] Based on minimum of 10 hr. operating day

[2] Will vary depending on *in situ* density of dredged sediment

Water quality monitoring revealed only a very limited impact on the water column from the actual dredging in terms of both PCBs and suspended solids. The detected elevations of these parameters were within the range of fluctuations normally found in the Harbor with changing environmental conditions. This limited impact was attributed to the bucket design and the method of operation. Larger increases in water column suspended solids and PCB concentrations were attributed to dredging support activities.

Flux chamber samples and ambient air samples were collected to achieve various objectives during the PDFT. Overall, this air sampling indicated that CDFs will be a more significant PCB emissions source than the dredging platform.

Results of the wastewater treatment pilot study showed that granular activated carbon when used with clarification and filtration can remove PCB concentrations to below the site-specific discharge limit of 0.065 milligrams per liter (mg/L) per Aroclor. The study also showed that sludge generated from wastewater treatment plant operations could be dewatered using a plate and frame filter press.

1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) entered into an Interagency Agreement with the U.S. Army Corps of Engineers, New England District (USACE) for the New Bedford Harbor (NBH) Superfund Site. Under this Interagency Agreement the USACE is providing EPA with technical assistance to implement the remediation plan selected in EPA's September 25, 1998 Record of Decision.

The remediation plan involves dredging of polychlorinated biphenyl (PCB) contaminated sediments throughout the Acushnet River estuary and New Bedford Harbor and placement of dredged material in shoreline confined disposal facilities (CDFs). Figures 1-1 and 1-2 provide site location maps of the New Bedford Harbor Superfund Site.

Prior dredging activities have been performed in the New Bedford Upper Harbor during the Pilot Dredging study in 1988 and 1989, and for the Hot Spot dredging in 1995. While these dredging events did demonstrate the use of a number of conventional and alternative hydraulic dredging systems, it was felt that changes in dredge technology over the years could improve upon past dredge production and other performance values.

In 2000, Foster Wheeler Environmental Corporation (Foster Wheeler) working with the USACE performed preliminary and detailed evaluations of available dredge technologies to meet the specific requirements of the full scale remediation project. The primary requirements of the dredge equipment for the New Bedford Harbor cleanup were to demonstrate accessibility for dredging of the Upper Harbor given the low bridge clearance and shallow water depths, minimize resuspension of contaminated sediments, provide acceptable dredging production, minimize water added during the dredging process and demonstrate necessary dredging accuracy. From review and discussion of these evaluations with USACE and EPA, it was decided to field test the most promising dredging systems, in a Pre-Design Field Test (PDFT) before final selection of the dredge system(s) for the full scale cleanup is finalized.

1.1 Objectives

To evaluate the performance improvements of a state-of-the-art environmental dredge technology over conventional dredge technology previously used at the site several performance areas were evaluated:

- Percent (%) solids concentrations in the dredge slurry and slurry pumping capabilities;
- Horizontal and vertical dredging;
- Dredge production rates in shallow water and sediment with debris;
- Potential impacts to water quality;
- Potential impacts to air quality; and
- Removal of the contaminated sediments to a given depth.

A secondary goal of the PDFT was to evaluate this new technology with regard to site specific cleanup levels. Additional objectives of the PDFT were to evaluate the effectiveness of applying contaminant dispersants and flocculents within the CDF to reduce PCB losses to air from the CDF, to evaluate mechanical dewatering methods for water treatment sludges and to evaluate the use of granulated activated carbon (GAC) to treat decanted seawater.

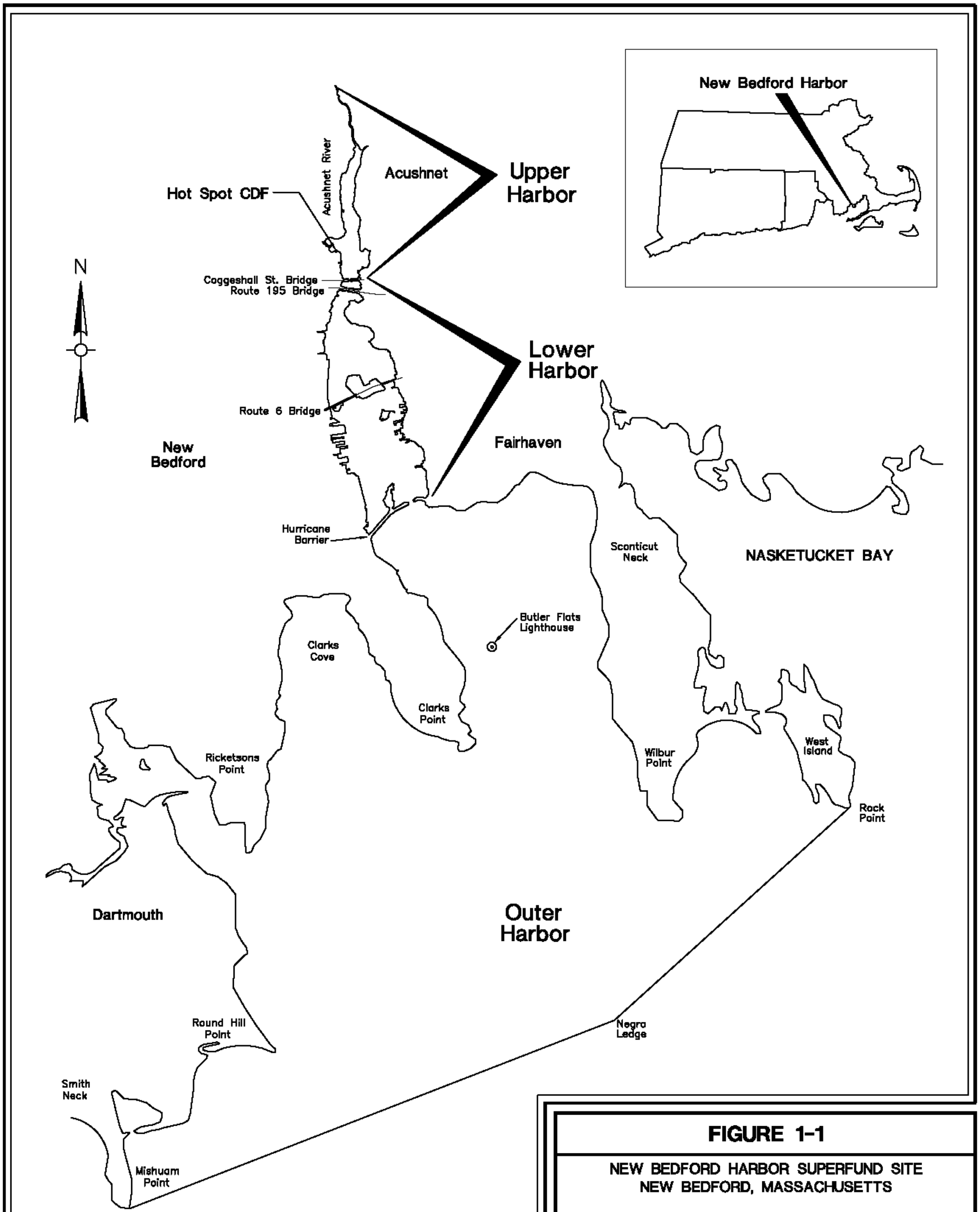


FIGURE 1-1

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

SITE LOCATION MAP

FOSTER WHEELER ENVIRONMENTAL CORPORATION
TERC PROGRAM

CADDFILE: SUPERFUNDSITE.DWG

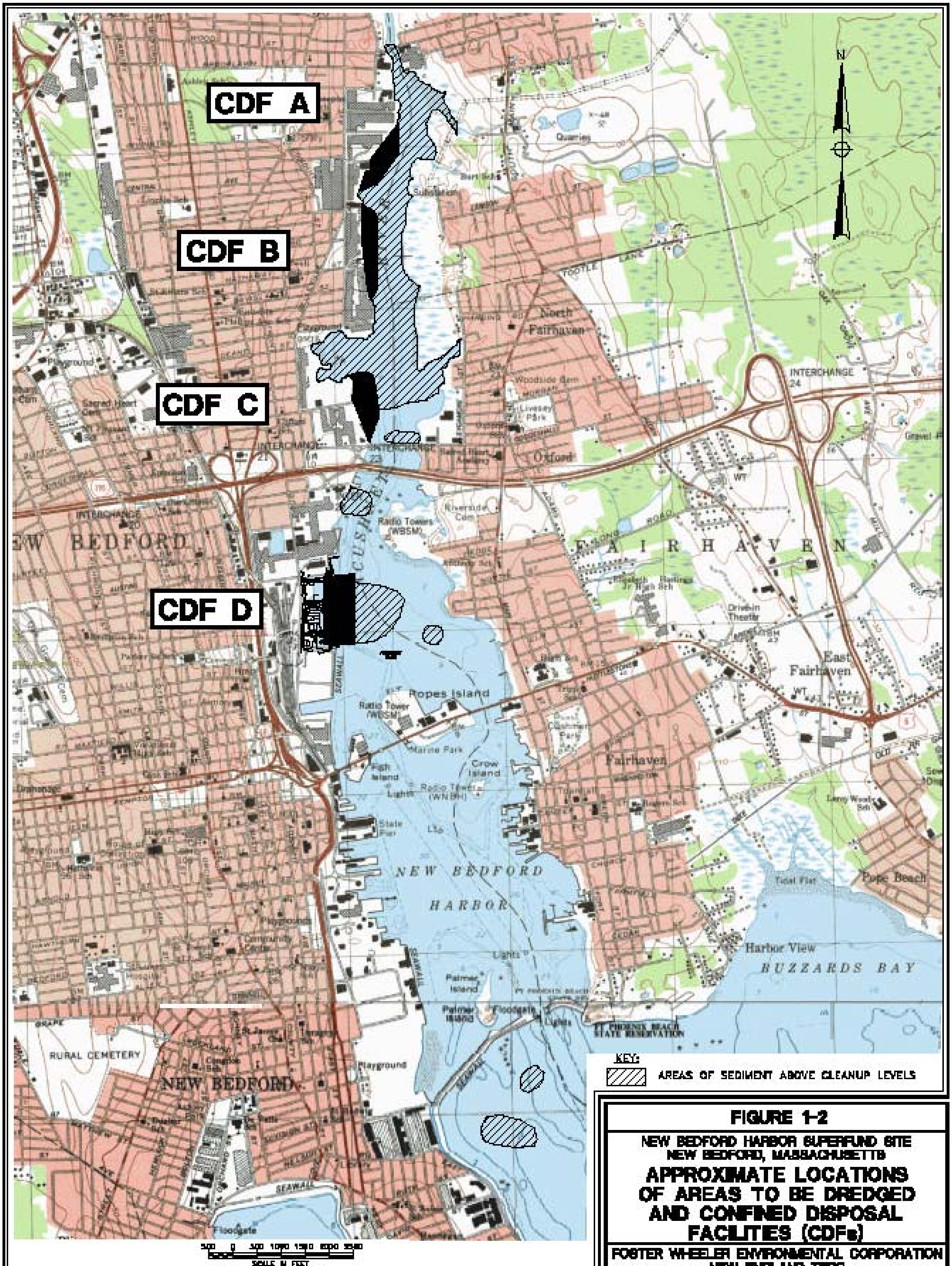


FIGURE 1-2

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

APPROXIMATE LOCATIONS OF AREAS TO BE DREDGED AND CONFINED DISPOSAL FACILITIES (CDFs)

CADDFILE: 5197N813.DWG

1.2 Pre-Design Field Test Plan

1.2.1 Dredge Technology Selection

The reports *New Bedford Harbor Cleanup Dredge Technology Review* (FWENC, 1999) and *Evaluation of Dredge Technologies, Phase Two - Detailed Evaluation* (FWENC, 2000a) were prepared to assist in the dredge technology selection for the full scale remediation project.

The report *New Bedford Harbor Cleanup Dredge Technology Review* (FWENC, 1999) provides a current assessment of the available dredge plant and support equipment that can be considered in determining how the environmental remediation dredging will be performed in New Bedford Harbor. The report evaluates potential dredging technologies that can address a set of specific challenges and criteria that have been identified in previous studies. These include the following:

- Maximize solids content and thereby reduce water volume and water treatment;
- Minimize re-suspension of contaminated marine sediments while dredging;
- Dredge in water depths of 1 to 4 feet (ft.) and intertidal areas;
- Perform precision dredging to minimize overdredging, which would add to the volumes of material requiring disposal in CDFs;
- Dredge in sediment having significant debris;
- Attain relatively high production rates; and
- Minimize or eliminate odors and PCB volatilization (control floatables and oils with specific emphasis on controlling contaminated oil releases during dredging).

As part of the *New Bedford Harbor Cleanup Dredge Technology Review* (FWENC, 1999) a dredge systems matrix was developed to organize and summarize the technologies that could meet the criteria established for the project. The following categories of information were investigated and summarized in the matrix for each dredge technology originally screened (Table 1-1).

Table 1-1
Dredge Technology Evaluation Matrix

Category	Specification
Dredge Type	Mechanical, Hydraulic, or Mechanical / Hydraulic (Hybrid)
Dredge Size (Plant)	Length x Beam x Height
Draft (ft.)	Loaded Draft (ft.)
Dredge Size (Pump / Bucket)	Pump Discharge Diameter (in.) or bucket size (cy)
Production Capacity	Working Production Capacity (cy/hr)
Debris Handling	Very Good, Fair or Poor
Vertical Cutting Accuracy (ft.)	Attainable Vertical Cutting Accuracy
Slurry Density	Advertised Slurry Density (% solids by weight)
Positioning / Monitoring System	Type, Accuracy
Surface oil collector	(Yes / No)
Sediment Re-suspension Minimization	(Good / Poor)
Projects Completed	Project Name Location Project Start / Completion Dates Volume of Sediment Dredged (cy) Pipeline / Haul Distance (ft.) Unit Cost ($/cy)
Dredge Cost	Cost to Purchase / Maintain Dredge

Over sixty (60+) dredge technologies available in the United States and internationally were initially screened for application on the New Bedford Harbor project in the report. Several preferred dredging systems and components were proposed for further evaluation by Foster Wheeler. Based on the project constraints, described above, the following dredge systems and components were proposed for further investigation.

Table 1-2
Dredge Technologies Selected in *Dredge Technology Review*

Manufacturer / Operator	Dredge Technology
Bean Technical Excavation Corporation	*Bonacavor* Hydraulic Excavator
Normrock Industries	*Amphibex* Amphibious Excavator
Aquarius Industries	Amphibious Excavator
DRE-Technologies	Dry-Dredge
Ellicott International	Series 370HP Hydraulic Cutterhead IHC Holland
WILCO Marsh Buggies Inc.	LGP Track Mounted Excavator
Quality Industries	LGP Track Mounted Excavator
Cable Arm Inc.	Cable Arm Environmental Clamshell
Miscellaneous	Land-based Earthmoving Equipment

These dredge systems and components represent existing available technology that have completed full scale environmental remediation projects and are believed to meet many of the New Bedford Harbor Cleanup Project parameters. These technologies were further screened and evaluated against the project criteria in the report *Evaluation of Dredge Technologies, Phase Two - Detailed Evaluation* (FWENC, 2000a). In this study contact was made with dredge technology representatives and project managers who are most familiar with the technologies. In some cases a site visit was made. Based on this intermediate evaluation, the dredge technologies having the highest probability for success in meeting the New Bedford Harbor project constraints were identified and proposed for further investigation by site demonstration or meetings with technology representatives.

These technologies were selected by Foster Wheeler and USACE project staff knowledgeable of the New Bedford Harbor project and performance parameters. They included the following:

- Bean Technical Excavation Corporation (Bean TEC) *Bonacavor*
- Normrock Industries *Amphibex*
- Ellicott International Series 370 hydraulic cutterhead dredge

Photographs of and technical data for these dredge systems are provided in Appendix P.

The studies concluded that dredging technology used for environmental remediation dredging has changed substantially since completion of both the New Bedford Harbor Pilot Dredging Study in 1988-1989 and the Hot Spot Dredging event in 1995. Prior studies had excluded mechanical dredging techniques for use on these two events due primarily to the inefficiency of barge transport to the disposal facility, because of shallow operating depths, the perception that a hydraulic system left a more uniform bottom surface, and concern over resuspension of contaminated sediments.

In the 1990's, in response to a growing number of environmental remediation projects, hybrid dredging systems (the mating of a mechanical excavation system and a hydraulic transport system) have been developed and used to successfully complete a number of full scale sediment remediation projects. The Bean TEC environmental hydraulic excavator *Bonacavor* and the Normrock Industries *Amphibex*, are two such systems that have completed full-scale projects, and would likely be well suited to complete portions of the full scale cleanup at New Bedford Harbor. Conventional hydraulic cutterhead dredge systems have also been successfully used to complete contaminated sediment removal projects, including the New Bedford Harbor Hot Spot Dredging, and could complete portions of the full scale cleanup successfully.

The Ellicott 370 hydraulic cutterhead dredge had been used during both the Pilot and Hot Spot dredging events, and to date, had provided the best all around performance results at the site. Significant testing and data collection regarding the dredge performance had been achieved for this dredge and documented. The Ellicott 370 hydraulic cutterhead dredge was therefore established as the baseline for comparison of the newer dredge technologies to be tested.

The Normrock Industries *Amphibex* was concluded to represent the most applicable type of "amphibious" dredge technology for the full scale cleanup in shallow and intertidal areas, and the manufacturer was approached to coordinate a field demonstration during the PDFT. At the time however, Normrock Industries, a Canadian firm, had manufacturing operations located only in Canada. Therefore, it's dredge, having been built on a foreign hull, was prohibited from operating in navigable waters of the U.S. under the Jones Act, and thereby precluded from participation in the PDFT. The company has since opened a manufacturing facility for the *Amphibex* in the United States, and as the hull is now not foreign built, it may be further considered for use on the New Bedford Harbor Cleanup, and other dredging operations in the U.S.

The PDFT therefore focused on the Bean type environmental hydraulic excavator for testing on the New Bedford Upper Harbor. Coordination between the Bean Dredging Corporation, the parent company of Bean Environmental LLC (BELLC), and Foster Wheeler was initiated in early 2000, for participation in development and demonstration of a Bean type environmental hydraulic excavator.

Foster Wheeler contracted with BELLC to develop a dredging system that enables selective dredging of the contaminated sediment, minimizes the amount of water added during the slurry pumping process, and recycles the dredge slurry effluent. This dredge system was a modification of the original Bean type environmental hydraulic excavator *Bonacavor*, used successfully on the Bayou Bonfouca Superfund project.

1.2.2 Dredge Performance Tests

The BELLC dredge and support systems were mobilized to the project site in late July 2000. With final assembly of the dredge system and movement into the dredge test area, the BELLC dredge underwent a series of performance tests. Dredge performance parameters monitored by Foster Wheeler and USACE during the field test are described below. Performance monitoring performed by BELLC is also described.

<u>Production Monitoring</u>

Dredge production monitoring was performed over the course of dredge operations in the PDFT test area. Dredging was performed both with and without operational controls (reductions in advance speed and dredge cycle time) to obtain representative production rates over a range of conditions, including varying water depths, depth of cut (bank height), and chemical and geotechnical conditions. BELLC collected production data using a number of electronic data collectors for the dredge systems, including flow meters, production meters, crane monitoring system, and slurry processing data. Foster Wheeler and BELLC production engineers also recorded excavator cycle time, and production delay data throughout the duration of the tests. Production monitoring data was summarized daily, and used as baseline for the following days tests. All production monitoring data collected over the course of the PDFT was assimilated, checked for quality, and screened for use in developing production ranges for the dredge that would be reflective of a full scale operation. The dredge production monitoring program results are presented in Section 3.0, Dredge Performance.

<u>Dredging Accuracy</u>

The BELLC dredge tested was specified to achieve average horizontal positioning and dredging accuracy of +/- 2 ft. or better and average vertical dredging accuracy of +/- 0.5 ft. or better. Initially it was planned that the USACE would measure the horizontal and vertical dredging accuracy, and to ascertain smoothness of the dredge cut including development of windrows, and “potholing” with daily post dredge bathymetric surveys. BELLC's bathymetric survey system however was setup to acquire the pre-dredge survey data for use as part of their dredge positioning and guidance system. The BELLC surveys were used for the PDFT. BELLC recorded the horizontal and vertical dredge excavation position on a continuous basis, as daily progress surveys. A final post-dredge bathymetric survey was conducted by BELLC over the test area, and verified by the USACE survey team. The dredging accuracy results and project surveys are presented in Section 3.0, Dredge Performance.

1.2.3 Environmental Monitoring

<u>Water Quality Monitoring</u>

Water quality monitoring was performed by the USACE subcontractor ENSR International (ENSR) during field testing of the BELLC dredge, to assess sediment resuspension at the point of dredging and downstream of the dredging operation. The dredge system to be tested, including support equipment, was capable of modifying dredge performance with operational controls to minimize resuspension of bottom sediments. The water quality monitoring program results are presented in Section 4.0, Environmental Monitoring.

Air Sampling

Foster Wheeler's subcontractor, The Kevric Company, performed ambient air sampling and analysis during the PDFT to document concentrations during operations. Locations were selected based on the proximity to dredging and CDF filling operations and included those around the CDF and near dredging operations on the eastern shore of the harbor. In addition, Foster Wheeler's subcontractor URS Corporation collected flux chamber samples to provide a measure of emissions as an indication of the relative contributions from the various operations to the ambient air concentrations. Flux chamber data will also be used to support the emissions and dispersion modeling calculations performed as part of developing ambient air action levels for upcoming construction work. Flux chamber and ambient air sample results are presented in Section 4.4.

2.0 PRE-DESIGN FIELD TEST DESCRIPTION

The PDFT was conducted to provide optimum, site specific dredge performance values for use in developing the New Bedford Harbor full scale remediation project. The PDFT demonstrated and recorded performance data including dredge production, accuracy, slurry solids concentration, air and water quality impacts. To provide the most realistic data for use in development of the full scale remediation project, the PDFT was conducted in areas and with equipment that would be reflective of the full scale project, to the extent possible.

2.1 Pre-Design Field Test Dredge Area

Location and Size

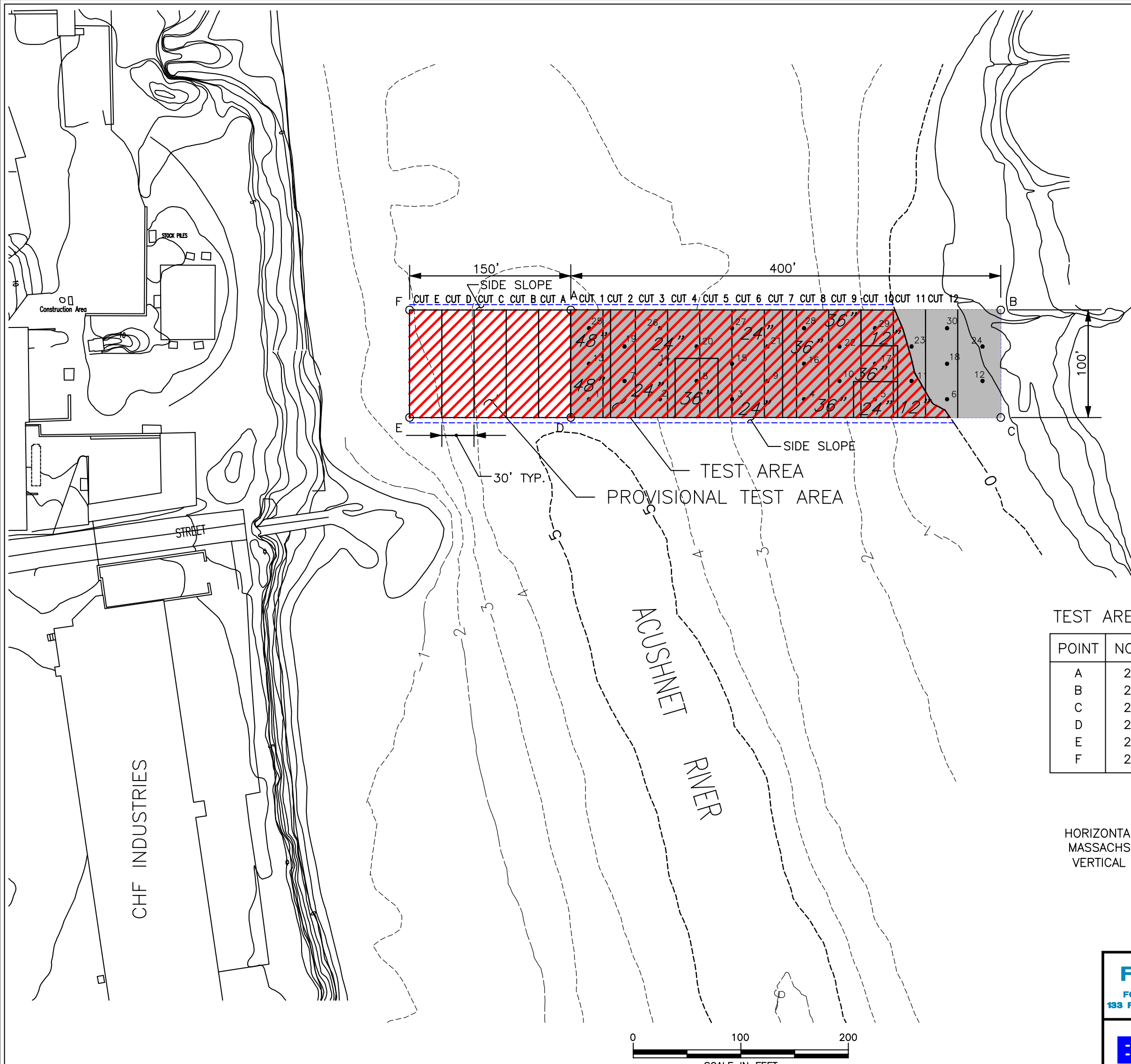
The PDFT test dredge area was selected by Foster Wheeler, EPA and USACE project personnel. A 100-ft. x 550-ft. dredge area, oriented east-west, located in the New Bedford Upper Harbor approximately 3,700 ft. north of the Coggeshall Street Bridge, was originally designated for the PDFT. The area, centered on relatively high levels, over 2,700 ppm of PCB contamination, would contain roughly 4,000 cubic yards (cy) based on a 2 ft. dredge cut. Also, the area ranged in depth from Mean Lower Low Water (MLLW) to -5 ft. MLLW, which is representative of depths in the Upper Harbor.

Analysis of a contaminant characterization program conducted in the PDFT test area and knowledge of the operational parameters of the BELLC dredge was used by Foster Wheeler, USACE and BELLC to develop a dredge plan that would provide a desired range of performance data during the PDFT. The PDFT dredge plan is shown as Figure 2-1. The dredge plan was based on depth and extent of PCB contamination as identified in sediment characterization data.

Dredge cut lanes were established, running north-south, each 30 ft. wide and 100 ft. long, with 2-5 ft. of overlap. As the dredge area transitioned across varying depth, debris, sediment type, and contaminant zones, each cut area provided discrete "sub-test" areas within which dredge performance monitoring would be performed. With concurrence from the PDFT monitoring team, the dredge area was also expanded to a 100-ft. x 150-ft. provisional test area to permit more dredge volume should it be needed, and to capture more deeply contaminated sediments located to the west of the original dredge area. The coordinates for the dredge test area (US State Plane 1983 Zone - Massachusetts Mainland 2001) are as follows:

N 2,704,050	E 815,100
N 2,704,050	E 815,650
N 2,703,950	E 815,650
N 2,703,950	E 815,100

The bed elevations within the dredge area ranged from roughly 0.0 ft. MLLW to -5.0 ft. MLLW. The minimum depth of cut in the dredge plan was 1 foot, while the maximum depth of cut was 4 ft. Materials dredged were hydraulically transported by the dredge via the discharge pipeline to the Sawyer Street CDF (CDF C). Figure A-1 shows PDFT project site including the Sawyer Street CDF. The maximum distance to the discharge within the CDF from the dredge site was 2,800 ft.



CORE LOG SAMPLING RESULTS

Core No.	Core Location		Pre-Dredge PCB Concentration (ppm)			
	Northing	Easting	0–1 ft	1–2 ft	2–3 ft	3–4 ft
1	2703967	815267	270	560	260	1.1
2	2703967	815333	200	6.0	0.17	
3	2703967	815400	810	6.2	0.36	
4	2703967	815467	2,700	23	0.13	
5	2703967	815533	210	0.63	0.12	
6	2703967	815600	11	0.0038		
7	2703984	815300	96	0.013		
8	2703984	815367	250	490	65	0.27
9	2703984	815433	2,500	2.2		
10	2703984	815500	2,300	27	0.11	
11	2703984	815567	29	0.084	0.0026	
12	2703984	815633	8.8	0.067	0	
13	2704000	815267	370	830	160	0.26
14	2704000	815333	320	0.79		
15	2704000	815400	830	3.0	0.16	
16	2704000	815467	2,500	94	0.41	
17	2704000	815533	460	24	0.0056	
18	2704000	815600	1.6	0.19		
19	2704016	815300	950	2.9		
20	2704016	815367	170	0.092		
21	2704016	815433	1,300	61	0.080	0.32
22	2704016	815500	1,100	64	7.4	7.2
23	2704016	815567	6.2	0.10	0.0030	
24	2704016	815633	4.5	0.032		
25	2704033	815267	460	420	1.2	
26	2704033	815333	330	4.4	0.33	
27	2704033	815400	480	0.82	0.059	
28	2704033	815467	1,000	300	0.062	
29	2704033	815533	67	0.66	0.15	
30	2704033	815600	5.5	0.042		

TEST AREA COORDINATES

POINT	NORTHING	EASTING
A	2704050	815250
B	2704050	815650
C	2703950	815650
D	2703950	815250
E	2703950	815100
F	2704050	815100

NOTE:
HORIZONTAL DATUM IS NAD83, MASSACHSETTS STATE PLANE, VERTICAL DATUM IS NGVD29

LEGEND

- •2 PRE-DREDGE CORE SAMPLE LOCATION
- 36" DREDGE CUT DEPTH
- TEST AREA
- AREA WITH CORE LOGS
- ----0---- MEAN LOWER LOW WATER (MLLW) IN FEET

FOSTER WHEELER
FOSTER WHEELER ENVIRONMENTAL CORPORATION
133 FEDERAL STREET, BOSTON, MASSACHUSETTS 02110

BEAN ENVIRONMENTAL, L.L.C.
ST. CHARLES AVE., SUITE 500
NEW ORLEANS, LA 70130

FIGURE 2-1

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

PRE-DESIGN FIELD TEST DREDGE TEST AREA

SCALE: AS SHOWN

CAD FILE: DREDGE_TEST01.DWG

Sediment Composition

Surface sediment ranged from fine-medium sands in the eastern, shallow portion of the test area, to high-water content silts in the western portion of the test area. The material composition within the subtidal portion of the dredge area was anticipated to be a combination of silt, sand, and clay. A recent sediment core from a location within 100 ft. of the dredge area contained 19% sand, 53% silt and 28% clay. In some subtidal areas near the test area, some organic (rooty matter) was encountered. The potential for encountering some cobbles, ballast stone or other debris, also existed, and is anticipated in many areas of the full scale cleanup. In the intertidal and emergent areas along the eastern end of the dredge area and on the shoreline within the dredge area, the sediment consists primarily of silty sand, with the sand component increasing from approximately 60% (40% silt) in the upper 12 in. to 80% (20% silt) 3 ft. below the surface. Geotechnical data for the Upper Harbor, including that in the vicinity of the test area, are provided in Appendix B.

Sediment Chemical Composition

The sediment in the test area was reported to have PCB contamination concentrations of between 0 and 2,700 ppm. Results of the sediment characterization program conducted prior to performance of the PDFT revealed PCB contamination in the dredge test area ranging from 1.6 to 2,700 ppm in the upper 12 in., 0 to 830 ppm at sediment depths from 12-24 in., and 0 to 260 ppm at sediment depths of 24-36 in. The PCB Core logs are provided in Appendix J.

Oceanographic Conditions

The PDFT was conducted near the center of the eastern subtidal and intertidal area of the New Bedford Upper Harbor. In general, wind wave heights in the Upper Harbor do not exceed 1-2 ft. The hurricane barrier and other restrictions across the Lower Harbor prevent ocean swell from propagating into the Upper Harbor. The mean tide range for the Upper Harbor is 3.7 ft., with a spring range of near 4.6 ft. Currents can vary sharply over the harbor area due to various constrictions. At the Coggeshall Street Bridge, the maximum ebb and flood currents are estimated to be 6.0 ft./sec and 3.0 ft./sec., respectively. The average ebb and flood currents are estimated to be 1.7 ft./sec and 1.1 ft./sec., respectively. Current speeds in the Upper Harbor average roughly 0.3 ft./sec., with a maximum of 0.85 ft./sec. The predicted tide record for the New Bedford Harmonic station for the period of performance of the PDFT is provided in Appendix C.

2.2 Pre-Design Field Test Team

The PDFT was performed by individuals from the following organizations:

EPA, New England – Overall responsibility for the PDFT.

USACE, New England District – Managed the joint efforts of Foster Wheeler and other USACE subcontractors in performing the PDFT. Responsible for third-party sampling efforts with Foster Wheeler's assistance, as well as general oversight of the test on behalf of the USACE and the EPA.

EPA, Narragansett, RI, Atlantic Ecology Division of the National Health and Environmental Effects Laboratory – Provided technical oversight of water quality monitoring and PCB removal efficiency study programs conducted during the PDFT.

Foster Wheeler – Prime construction and engineering contractor responsible for implementing the PDFT and management of subcontractors on site. Responsible for developing the dredge test plan, dredge performance monitoring, air quality monitoring and laboratory analyses, coordination of sediment dewatering and volatilization testing, and water treatment treatability and influent testing of supernatant in the CDF. Conducted ambient air sampling and analyses.

BELLC – Dredge contractor responsible for the design, development, mobilization and performance of state of the art hybrid test dredge demonstrated for PDFT.

ENSR International – Subcontractor to USACE. Responsible for water quality monitoring analyses and collection and analyses of PCB removal efficiency data during PDFT test.

URS – Subcontractor to Foster Wheeler Environmental for flux chamber sampling.

Kevric – Subcontractor to Foster Wheeler Environmental for ambient air monitoring.

CR Environmental – Provided oceanographic data recording equipment and vessel for water quality monitoring.

2.3 Dredge System

Under USACE Contract No. DACW33-94-D-0002, Task Order No. 17, Foster Wheeler subcontracted with BELLC for the delivery and demonstration of a modification of the *Bonacavor* environmental hydraulic excavator to work along with the Slurry Processing Unit (SPU) previously patented by C.F. Bean Corporation, now C.F. Bean L.L.C., an affiliate of BELLC. In response to the contract specifications and numerous meetings between Foster Wheeler, BELLC, and the USACE, BELLC mobilized and demonstrated a hybrid dredge (mechanical excavation/hydraulic transport), based on the Bean type hydraulic excavator platform with SPU. Final design and construction of the dredge's components and systems were carried out at BELLC's Belle Chasse, Louisiana marine yard, outside New Orleans. Dredge systems were assembled at the yard, tested and debugged, disassembled and transported to New Bedford, Massachusetts, for final assembly and mobilization into the PDFT area.

The dredge system mobilized and demonstrated by BELLC at the New Bedford site was comprised of:

- A portable, shallow draft barge platform, with fully loaded draft not to exceed 2.0 ft. The equipment barge and ancillary support vessels were also to be provided with loaded draft not to exceed 2.0 ft.
- A hydraulic excavator with a sealed environmental clamshell bucket. The Profiling Grab bucket designed by Boskalis Dolman and presented at prior meetings between BELLC, Foster Wheeler and the USACE was used for the field test. The BELLC dredge system was to be capable of maintaining at least a 100 cy/hour production rate. The dredge system was also to be capable of providing horizontal positioning accuracy of +/- 2 ft. or better and vertical dredging accuracy of +/- 0.5 ft., or better.
- The SPU was to be incorporated into the design of the environmental hydraulic excavator, as a means of providing relatively high and controllable solids concentrations of the dredge slurry. The SPU was to be capable of maintaining at least 30% solids by weight in the dredged material slurry over the course of a dredging day.
- A water recirculation system that would demonstrate the practicality of recycling decant water from the Sawyer Street CDF as makeup water for hydraulic dredged material transport.
- A discharge pipeline for transport of the dredge slurry to the Sawyer Street CDF.

- Capabilities for providing continuous dredge production data, including discharge flow rate, solids concentration, material production, cycle times, and advance rate. The dredge system also provided dredge and excavator position data on a continuous basis.

Additional materials mobilized to the test site and maintained by BELLC over the duration of the PDFT included the following:

- Oil containment boom, deployed around the point of dredging to contain the oil/PCB sheen.
- Appropriate dredge positioning and navigational aids.
- Appropriate health and safety equipment, including provisions for operations under Level C HAZMAT conditions, if required.
- Support equipment, including personnel transport, setup and dredge plant positioning equipment.

The BELLC portable dredge system developed and tested during the PDFT consisted of the primary components presented in this section. A schematic plan of the dredge as assembled and dredge system cut sheets showing additional details are provided in Appendix D. Various PDFT project photos of the BELLC dredge are provided in Appendix O.

The primary components of the BELLC dredge that distinguish it as a system particularly well suited to perform environmental dredging in the New Bedford Upper Harbor, are the Horizontal Profiling Grab bucket (HPG), the Crane Monitoring System (CMS), the SPU, and the Recirculation system. These components are described in greater detail to convey a thorough understanding of the overall system. Other major components of the dredge are also described in this section.

2.3.1 Dredge Platform

Due to access restrictions by water to the Upper Harbor, cost limitations, and to allow for a dredge system with minimal draft, the installation of heavy equipment, and the use of relatively simple barge shifting devices, the BELLC dredge platform for the PDFT was fabricated using a modular system of interlocked Flexi-Float pontoons. As the Coggeshall and Highway 6 bridges present a height restriction of 8 ft. at Mean High Water (MHW), and the design height of the BELLC dredge was 25 ft., only the barge platform was fabricated in the Lower Harbor. The Flexi-Float units were transported by truck to the MAT Marine yard on Fish Island, just south of the Hwy 6 bridge. Fifteen (15), 40 ft. x 10 ft., Series S-50 Flexi-Float modular pontoons, each 5 ft. in height were used in the fabrication of the BELLC dredge platform (Figure 2-2). The dredge configuration was unconventional in that it was as wide (80 ft.), as it was long (80 ft.). This low aspect ratio provided a large and stable footprint upon which to mount the significant on-board dredge systems, while still maintaining a relatively shallow draft, due to a greater distribution of weight. The draft of the dredge barge with all systems installed was designed to be 2 ft.

Figure 2-2
BELLC Test Dredge Under Construction

A key feature of the dredge was incorporation of a "moonpool", a 30 ft. long x 40 ft. wide cutout, at the digging end of the barge where the excavation actually took place. The moonpool concept permitted the dredging to be conducted within an isolated and relatively quiescent area, enclosed on three sides by the barge sidewalls, with the bow opening closed by a floating oil boom with 3 ft. deep curtain. The moonpool served to "encapsulate" the dredge area, providing for decreased wave action at the point of dredging and entrained any surface sheen within the 30 ft. x 40 ft. area. Once the dredging of an area corresponding to a “moonpool” or “spud” position was finished, the barge was shifted to a position north or south, to dredge an adjacent area.

Two (2) 20-inch diameter spuds, each 40 ft. long, of integrated Flexi-Float design were installed on port and starboard sides of the dredge, approximately 56 ft. aft of the bow. A four-point anchoring system, with two (2), manually operated, dual-drum diesel winches, was selected for dredge mobility and positioning. Electric and hydraulic power units were installed for anchor and spud winch systems.

2.3.2 Horizontal Profiling Grab (HPG) Bucket

One of the primary recommendations of the *Dredge Technology Review* and a goal of the PDFT was to apply mechanical dredging equipment to the New Bedford Harbor cleanup site. It was believed that excavation using a mechanical clamshell bucket could provide optimum dredging production, debris management, and dredging accuracy for the New Bedford Harbor site specific conditions. The mechanical bucket selected for use with the BELLC dredge tested during the PDFT was the HPG. The HPG was developed by Royal Boskalis Westminster n.v., BELLC’s European partner firm, and has been used successfully on environmental remediation projects in the Netherlands and Europe involving dredging of contaminated sediments. Both 4.5 cy and 3.25 cy HPG buckets were imported to the United States for demonstration on the PDFT. PDFT production goals and excavator capacity necessitated only the testing of the 4.5 cy bucket (Figure 2-3).

Figure 2-3
Horizontal Profiling Grab Bucket

In practice, the advantages of the HPG bucket design over conventional mechanical buckets include:

- During closing, the bucket's leading cutting edges follow a horizontal line, by means of specifically designed pistons, allowing a horizontal cut over a relatively large surface. This permits selective dredging of thin horizontal layers.
- The maximum opening of 14.75 ft. is approximately 80% longer than a conventional clamshell bucket. This makes it possible to reach optimal fill of the bucket even when operating in relatively thin layers. The result is high production even when dredging thin layers.
- The incorporation of a 360^{o} horizontal rotor between the excavator-stick and the HPG bucket allows the bucket to be positioned in such a way that the cutting pattern consists of adjoining, parallel rectangles. The result is a more controllable dredge cut pattern with minimal overlap and maximum dredging efficiency. Less overlap between cuts also serves to reduce turbidity and spill.
- Because the HPG bucket is actively closed by hydraulic cylinders with good breakout forces, as opposed to closing wires, its vulnerability to debris has proven to be minimal. The speed of closing and opening is also relatively low to minimize resuspension of sediments.

- The HPG bucket is fitted with vents, three (3) on the top section of each bucket half, each approximately 12-in. x 16-in., which open when the bucket opens and close when the bucket closes. In this manner the bucket encloses the contaminated sediments and minimal turbidity and spill is generated during the lifting of the bucket through the water column and above water. During lowering the bucket in the water, the air enclosed in the bucket escapes immediately when the bucket is submerged, thus avoiding turbidity created by the release of entrapped air at the moment when the bucket is closing.
- The horizontal and vertical position, and rotation angle of the bucket is determined by the Real Time Kinematic (RTK) Differential Global Positioning System (DGPS) in combination with the measurement of angles of all movable parts on the excavator.
- The HPG bucket is integrated with the CMS where real-time bottom level, bucket position, rotation, and dredged depth are monitored. Design and actual bottom levels are incorporated in a Digital Terrain Model (DTM).

2.3.3 Hydraulic Excavator

A Caterpillar 375LC hydraulic excavator (backhoe) with a 27 ft. 6 in. boom and an 18 ft. 1 in. stick was selected as the optimal machine with which to operate the HPG bucket (Figure 2-4). The total weight of the 375LC is approximately 180,000 pounds (lbs). Modifications were made on the excavator's hydraulic system to incorporate all rotation and closure functions of the HPG at relatively low speed to avoid turbidity during dredging. The 375LC was equipped with centimeter level accuracy RTK DGPS and the CMS, described in further detail below. The operators cabin was provided with overpressure fresh air using the BM-Air MAO-5 Pressure Filter System, a unit equipped with heavy-duty dust and carbon filters. The excavator was placed on wooden mats aft of the moonpool and fixed to the barge by means of steamboat ratchets.

Figure 2-4
Caterpillar 375 LC Hydraulic Excavator with Horizontal Profiling Grab Bucket

2.3.4 Crane Monitoring System (CMS)

The CMS is an on-board electronic sensor system that provides the crane operator maximum control of the bucket while dredging, both in the horizontal and vertical planes. The CMS combines signals from the excavator boom, stick, and bucket hinges, signals from the swing of the excavator, the horizontal and vertical position (including tide) of the RTK antenna, and the list, trim and orientation of the barge. These signals are assimilated in a computer that displays the entire dredge system in a graphical format with the pre-dredge hydrographic survey and the design dredge prism. In using the CMS, the operator dredges in pre-programmed dredge sets based on a planned horizontal and vertical grid. A heads up display installed in the operators cab gives a record of the historical bucket position and grade achieved for every set of the dredge. The CMS display monitors were also provided in the control room and the visitor's room during the PDFT. Figure 2-5 shows the typical CMS screen in the operator’s cab. Via telemetric link, the CMS display can also be provided to a landside office, in real time, in proximity to the dredge area.

The CMS as installed on the BELLC Test Dredge consisted of the following elements:

- A Sercel Aquarius 5002 RTK DGPS receiver, providing +/- 2 in. accuracy in the X-Y and Z planes.
- A Sperry SR220 Gyrocompass and digital repeater for barge heading providing accuracy of +/- 1 degree.
- List and trim measurement for the barge with accuracy +/- 0.1 degree.
- Measurement of the following movable parts of the excavator and the HPG to calculate the precise dredging position of the HPG bucket in X, Y and Z. All angles were measured with an accuracy of +/- 0.1 degree.
  - Swing angle, excavator to barge
  - Boom-angle
  - Stick-angle
  - Rotation angle of the grab
- A computer system that generates graphical displays with real time plan and profile views of the equipment, the dredge area, dredge grade, dredged areas and elevations, and the mudline, based on a DTM of the PDFT area. Computer monitors were located in the excavator operator’s cabin, the control room, and the visitor’s room. Dredged depths and positions were logged and stored continuously.

2.3.5 Slurry Processing Unit (SPU)

General

Minimizing the amount of water added to the dredged material was a focus area of the PDFT, as a significant portion of the overall full scale remediation cost will be attributed to the management and treatment of the effluent water from the dredge slurry. To minimize the amount of water to be delivered to the CDFs, the design team intended to test the Bean patented SPU (Figure 2-6), which has been used successfully on other environmental remediation projects to achieve solids concentrations in the dredge slurry averaging over 20% solids by weight.

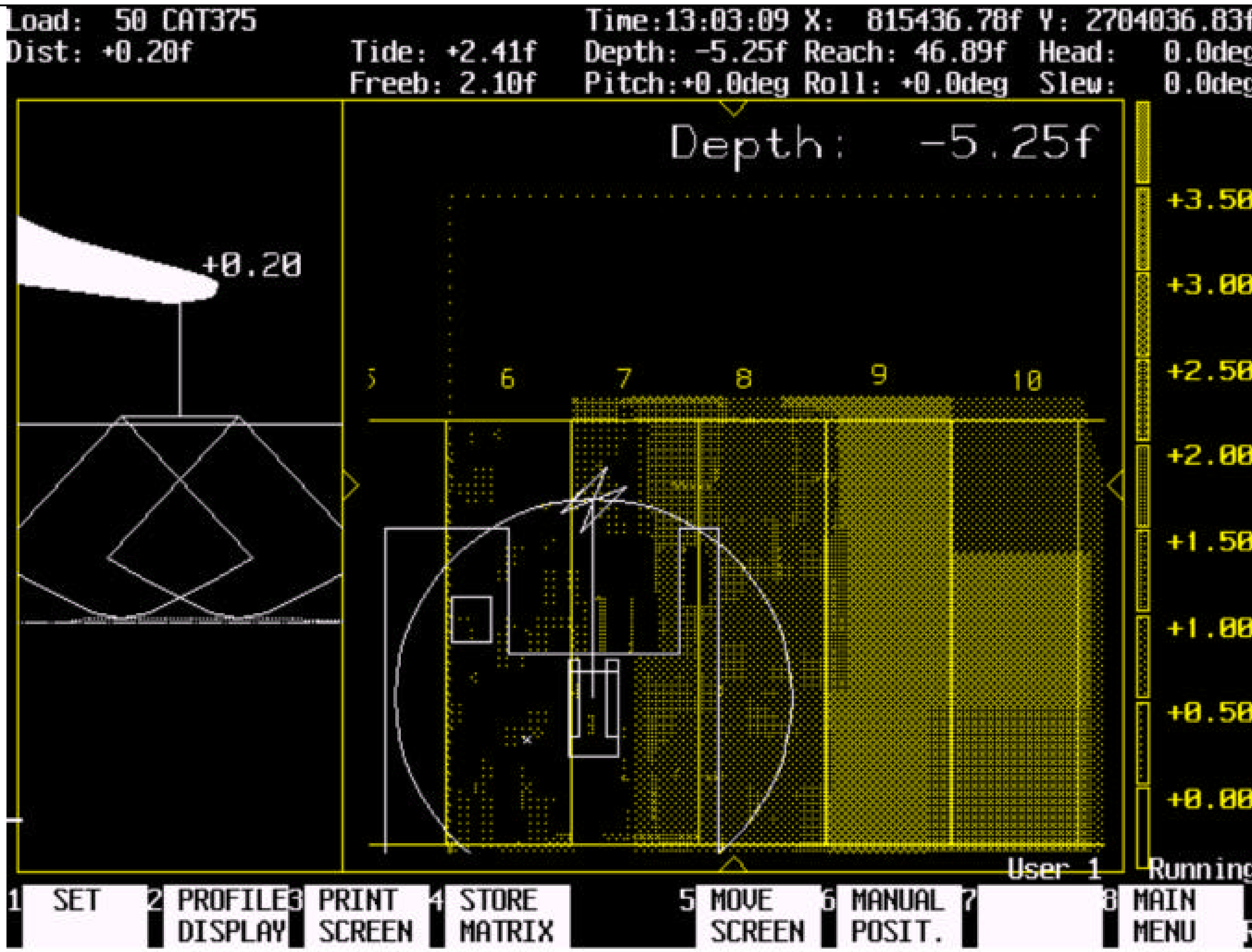


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FIGURE 2-5

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

CRANE MONITORING SYSTEM HEADS UP DISPLAY

NOT TO SCALE

CAD FILE: NBH_IMAGE-1.DWG

The SPU system is a proprietary hydraulic slurry transport system that delivers high percent solids concentrations, by introducing controlled amounts of water to mechanically dredged material. The *in situ* material conditions dictate the theoretical maximum achievable slurry density (i.e., it is not possible to achieve solids concentrations that are higher than that of the *in situ* material).

Sensors located on three specific gravity loops (inverted u-tube manometers) placed along the discharge line on board the dredge measure parameters by which the solids maximization process is managed. The SPU system can be operated in manual or automatic mode. In automatic mode the SPU operator selects the upper and lower limit values for the slurry density and for the discharge velocity. Based on the measured values of slurry density, and comparison with the *in situ* density ranges for the dredge area, the computer will adjust the slurry pump speed and/or add water to the system. In manual mode the SPU operator, not the computer, adjusts the slurry pump speed and/or adds water to the system. He also instructs the excavator operator to add more or less sediment to the system.

A key feature of the SPU is the ability to input decant water from the disposal site back into the system, thereby substantially reducing the overall quantity of water added to the CDF, and reducing the amount of water that must be treated.

Figure 2-6
Slurry Processing Unit

<u>SPU System Operation</u>

Operation of the SPU system begins with debris separation after placement of the dredged material by the HPG bucket on the 6-inch x 6-inch grizzly screen of the process hopper. To manage the debris and stiffer material that would not pass or become lodged on the grizzly screen, an elevated mini-excavator was installed adjacent to the grizzly in order to mash cohesive soils through the grizzly and to remove debris from the grizzly and deposit them in the trash bin. On the bottom of the hopper, two horizontal augers were installed to homogenize the dredged material and to reduce the (shear-) strength of the sediment to prepare the optimal mixture for the hydraulic transport. This step would further serve to increase slurry density while minimizing pipeline resistance. The augers can turn both ways in order to release debris in case of obstruction. Additionally, a "rockbox" with a 4-inch x 4-inch screen was installed in the suction line between the hopper bottom and the main slurry pump.

The SPU controls system measures hopper level, suction pressure and mixture velocity along the suction line. Suction pressure and/or velocity readings below pre-set operating ranges indicate to the SPU operator the presence of higher than desired densities or suction line blockage.

After discharge from the 12-inch centrifugal pump, the slurry enters the first specific gravity (SG) loop with electronic pressure transducers. The transducers provide the information to the process computer to calculate slurry density and estimate transport pipeline losses. The density measurement is compared to a density set point, based on the *in situ* characterization of the dredge area, and appropriate adjustments (addition of water) are made by the computer system. The same measurements are carried out in a second SG loop, and again the necessary adjustments are made. The third and final SG loop together with the electromagnetic velocity meter measures and records the final solids concentration of the slurry as it is pumped from the dredge to the Sawyer Street CDF.

The 2,800 ft. discharge pipeline was an 8-inch diameter (inner diameter 7.13 in.) fused high density polyethylene (HDPE) line. The same specification and length of pipeline was used as the return water line. Both discharge and return water pipelines were lashed to and floated by a 16-inch HDPE pipeline, plugged at both ends. When the discharge line was loaded with dredge slurry, it had a tendency to sink. When the return water line was full, it was more or less neutrally buoyant. The dredge slurry was discharged roughly halfway along the eastern wall in Cell 1 of the Sawyer Street CDF.

2.3.6 Recirculation System

The SPU system is intended to minimize the amount of water to be added to the dredged material such that the dredge slurry density would be optimized. However, the water that is added to the hydraulic transport system still requires storage capacity and ultimately, treatment. Due to the full scale project parameters of large dredging volume, requirement for hydraulic transport due to shallow water, and limited CDF capacity, efforts were made to develop a system which would serve to further minimize the volume of discharge water to be managed on the full scale project. A water recirculation system was therefore included for testing in the PDFT.

The recirculation system involved the pumping of decant water from the CDF with a self priming 8-inch diesel driven pump (Figure 2-7), via an 8-inch diameter fused HDPE pipeline, back to the dredge for use as make-up water, thereby creating a closed loop system.

The make up water system for the SPU can be obtained from either return water from the CDF or harbor water via a sea chest. During the PDFT dredging, however, only return water from the CDF was used to supply the make-up water pump installed on board the dredge. The make-up pump increased the pressure of the make-up water to a maximum of 150 psi. The make-up water supply, available at a charged manifold, was used by BELLC for a number of operations, including SPU water injectors, suction line debris jets, and the mini excavator (grizzly) debris jet.

Figure 2-7
Recirculation System Return Water Pump, Cell 2

2.3.7 Support Vessels and Equipment

As with any dredging operation, support vessels and equipment are needed to facilitate the process. For the PDFT, BELLC mobilized the following:

Hydrographic Survey Equipment

- Twenty-six foot (26 ft.), shallow draft, twin screw aluminum survey boat.
- Trimble 4000 SSE Sub-meter level RTK DGPS reference station for horizontal positioning.
- Odom Mark II DF3200 dual frequency echosounder.
- Survey computer with SSD dredge navigation and data acquisition and processing software.

Support Vessels

- Twenty-seven foot (27 ft.), shallow draft tender tug, "Miami II".
- 30 ft. x 65 ft. Equipment barge for staging and transportation of equipment and trash boxes with a 15-ton telescopic hydraulic crane.
- Twenty-one foot (21 ft.), shallow draft, Carolina Skiff.

2.4 Chronology of Events

The PDFT was scheduled to be performed in the late July 2000, early August 2000 timeframe. The contract was structured to permit five to ten (5-10) days of dredge performance testing and monitoring. The chronology of events for the PDFT on site activities is as shown in Table 2-1.

Table 2-1
PDFT Chronology of Events

Activity	Date
Mobilization	July 19 - August 7, 2000
Dredge Systems Setup and Calibration	August 7 - August 10, 2000
Trial Dredging, Day 1 (Cut 6)	August 10, 2000
Trial Dredging, Day 2 (Cut 6)	August 11, 2000
Trial Dredging, Day 3 (Cut 6)	August 12, 2000
Trial Dredging, Day 4 (Cuts 6)	August 13, 2000
Test Dredging, Day 5 (Cuts 7,8)	August 14, 2000
Test Dredging, Day 6 (Cuts 8,5)	August 15, 2000
Test Dredging, Day 7 (Cuts 5,4,3)	August 16, 2000
Test Dredging, Day 8 (Cuts 3,2,1)	August 17, 2000
Test Dredging, Day 9 (Cuts 1,A)	August 18, 2000
Demobilization	August 19 - August 30, 2000

2.5 Meteorological Conditions

Meteorological data was collected over the course of the PDFT at the Sawyer Street meteorological station, located near the northeast corner of the site. The daily raw meteorological data sheets for the period of performance are provided in Appendix C. A daily summary of the meteorological conditions encountered on site during the PDFT is provided in Table 2-2. Over the period of performance of the PDFT, the weather conditions ranged from clear and sunny with little wind, to periods of moderate rain (approaching 0.5 in. over course of production day), and wind speeds reaching 15-18 miles per hour.

2.6 Health & Safety Plan

The PDFT was conducted in accordance with the Environmental, Health & Safety (EHS) Program, and the Site Safety and Health Program (SSHP), as facilitated by Foster Wheeler's EHS personnel. EHS personnel also performed real-time and integrated air monitoring on site and on the test dredge to ensure compliance with established occupational exposure limits, as well as sampling of personal protective equipment (PPE) for disposal characterization. No major health and safety related incidents occurred during the PDFT.

Table 2-2
PDFT Meteorological Data Summary

Date	Average Windspeed [1] (mph)	Maximum Windspeed [1] (mph)	Average Wind Direction [1]		Average Temperature [1] (degrees F)	Average Barometric Pressure [1] (inches Hg)	Average Rainfall [1] (inches/hr)	Total Rainfall [2] (inches)
			(0 N)	Compass				
8/10/00	7.45	10.32	309	WNW	81.80	29.79	0.008	0.450
8/11/00	11.10	15.38	89	ENE	77.41	29.88	0.006	0.070
8/12/00	15.16	17.39	53	ENE	70.64	29.89	0.000	0.000
8/13/00	11.63	14.99	53	ENE	68.32	29.91	0.016	0.460
8/14/00	13.52	16.66	43	NNE	68.83	29.88	0.002	0.250
8/15/00	10.59	12.60	29	NNE	69.21	29.96	0.029	0.320
8/16/00	8.37	10.92	222	SSW	74.58	29.78	0.004	0.040
8/17/00	9.01	11.20	294	WNW	71.74	29.89	0.000	0.000
8/18/00	6.71	10.04	126	ESE	69.10	29.95	0.000	0.060

[1] Average over duration of testing 0700 hrs - 1700 hrs

[2] Daily Total

3.0 DREDGE PERFORMANCE

The PDFT was undertaken to evaluate the performance of hybrid mechanical/hydraulic environmental dredge technology with the Bean type SPU. This technology was selected as one of the most applicable dredging system to be used for the full scale remediation based on the results of *the Dredge Technology Review* and *Evaluation of Dredge Technologies, Phase 2 - Detailed Evaluation* studies completed in 2000.

Three main dredge performance areas were evaluated during the PDFT: 1) dredge performance in removal of PCB contaminated sediments; 2) ability to minimize water quality impacts; and 3) ability to minimize air quality impacts. To measure and record performance that could be extrapolated and used in the development of the full scale remediation project, a minimum of five (5) days and a maximum of ten (10) days of test dredging with the BELLC dredge system was planned.

The specific areas of testing for evaluation in the main performance areas included the following:

1) PCB Removal
   - Dredge production over a range of conditions
   - Dredging accuracy
   - Solids concentration of the dredge slurry
   - Recirculation system effectiveness
   - PCB removal efficiency
2) Water Quality
   - Water quality impacts within the Upper Harbor caused by dredging operations
3) Air Quality
   - Ambient air sampling at the point of dredging and at the CDF

The remainder of Section 3.0 describes dredge system performance in PCB removal. The following section, Section 4.0, describes results of water and air quality monitoring, and flux chamber sampling.

3.1 PCB Removal - Dredge Performance Testing

<u>Overview</u>

The PDFT testing schedule was established to ensure that dredge performance testing and monitoring required of the PDFT would be captured over 5-10 days of dredging. The actual schedule changed from an original planned schedule to incorporate modifications to dredging parameters as determined by the prior days dredging, by the PDFT team. The PDFT was scheduled to be performed in the late July 2000, early August 2000 timeframe.

The PDFT test schedule followed the chronology of events as summarized in Table 2-1.

BELLC began dredging operations in Cut 6, and after performing systems calibrations and modifications or "trial" dredging exercises over the course of August 10-13, proceeded to the east into shallower water. The easternmost cut dredged was Cut 8. Thereafter BELLC moved to Cut 5 and proceeded to the west, terminating test dredging in Cut A, in the provisional dredge area. In total, 4 days were spent performing trial dredging during which the dredge system underwent modifications to prepare for test dredging, while test dredging was performed over the course of 5 days. The dredging progress over the duration of the PDFT in-water work is shown on Figure 3-1.

Dredge performance testing results as it relates to the actual removal and transportation of PCB contaminated sediments as observed during the PDFT are presented in this section. Conclusions and recommendations pertaining to performance values for use in designing the full scale remediation are presented in Section 6.4.

3.1.1 Dredge Production

Dredge production monitoring was performed over the course of dredging operations in the PDFT test area. Dredging was performed to obtain representative production rates over a range of conditions, including varying depths, depth of cut (bank height), and chemical and physical conditions.

BELLC collected production data using a number of electronic data collectors for the dredge systems, including flow meters, production meters, CMS, and slurry processing data. Foster Wheeler and BELLC production engineers additionally recorded excavator cycle time, and production delay data throughout the duration of the tests. Production monitoring data was summarized daily, and reviewed by the PDFT team during the daily planning meeting the following day. An example of a daily production report, for August 17, is shown on Figure 3-2. The complete production records for the PDFT are provided in Appendix E.

The production performance of the PDFT test dredge, a hybrid system involving mechanical excavation and hydraulic material transport, is based on two main processes; material excavation, and materials transportation. These processes, while integrated, should be evaluated separately, in order to more precisely determine the production limits of the dredge system as a whole. This production evaluation method can be adapted for other dredging processes involving either hydraulic dredging, mechanical dredging with barge transportation and rehandling of dredged material, or other hybrid systems. Delays due to dredge advance, debris separation, mechanical repairs, weather, navigation and other factors, can influence either or both the excavator or hydraulic transport production efficiency, as can the operational controls instituted to perform environmental dredging. The key parameters affecting dredge production on site are discussed below.

Excavator Production

The BELLC dredge excavation system consisted of a Caterpillar 375 LC hydraulic excavator with 4.5 cy HPG environmental clamshell bucket. The dredge was designed to provide vertical dredging accuracy exceeding +/- 0.5 ft., and horizontal dredging accuracy exceeding +/- 2 ft., through integration of the excavator and clamshell bucket with a RTK DGPS and the CMS.

The base excavator production of the dredge, which represents the fastest production rate the dredge can attain, is based on the cycle time of the grab, including time required to position the bucket over the dredge cut, lower the bucket to the desired grade, close the bucket, raise the bucket, swing the bucket to the material hopper, open the bucket over the hopper while material drains out, and return the bucket to the next dredge cut. The average digging depth of the bucket was 5 ft. below the water surface, with an average swing angle of 62 degrees. The excavator lifted the bucket 25 ft. above the surface of water.

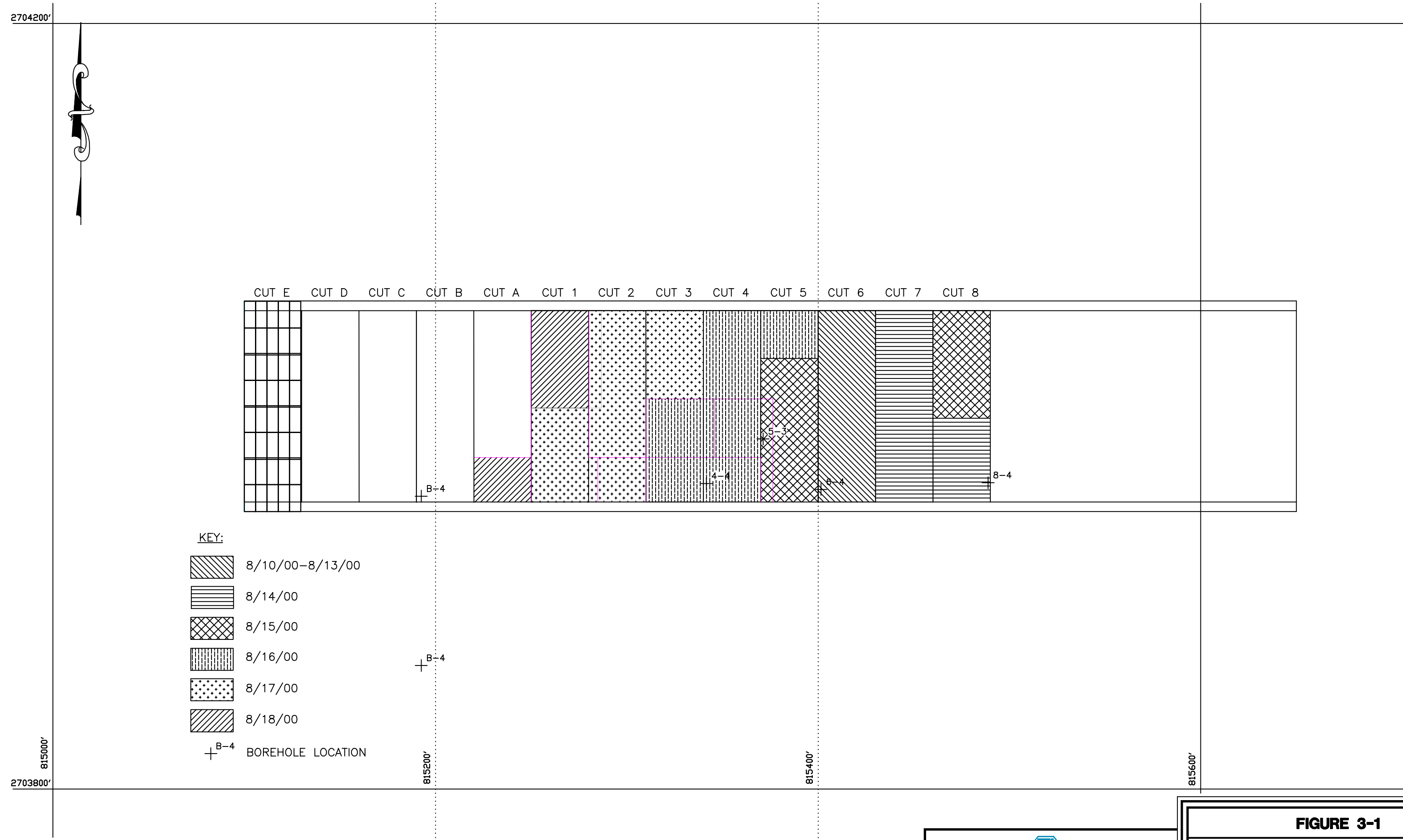

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FIGURE 3-1

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

DAILY DREDGING PROGRESS

SCALE: AS SHOWN

CAD FILE: 29088db004A-1.DWG

Figure 3-2
Daily Production Report, August 17, 2000

New Bedford Harbor Superfund Site, Pre-Design Field Test
BEAN Environmental L.L.C., Test Dredge
Daily Production Report **Date:** **August 17-2000**

Dredging			Cut No.	spudpos.	Dredge	Delay			delay
from	till	time	[1,2,3,4]	[1,2,3,4]	layer(ft)	from	till	time	description
						9:30	10:22	0:52	Start up, move dredge into position,etc
						10:22	10:27	0:05	Backwash
10:27	10:45	0:18	3	3	1.5/2.0*	10:45	10:47	0:02	Trash on grizzley hopper
10:47	10:50	0:03	3	3	1.5/2.0*	10:50	11:00	0:10	Shift to Cut 3, pos 2
11:00	11:40	0:40	3	2	1.7	11:40	11:45	0:05	Shift to Cut 3, pos 1
11:45	12:07	0:22	3	1	1.7	12:07	12:09	0:02	Backwash
12:09	12:23	0:14	3	1	1.7	12:23	12:41	0:18	Shift to Cut 2, pos 1
12:41	13:08	0:27	2	1	1.7	13:08	13:50	0:42	Clean Rockbox
13:50	13:56	0:06	2	1	1.7	13:56	13:59	0:03	Backwash
13:59	14:10	0:11	2	1	1.7	14:10	14:19	0:09	Shift to Cut 2, pos 2
14:19	14:31	0:12	2	1	1.7	14:31	14:34	0:03	Trash on grizzley hopper
14:34	14:38	0:04	2	1	1.7	14:38	14:49	0:11	Trash on grizzley hopper,karts,cable,chain
14:49	14:55	0:06	2	1	1.7	14:55	15:00	0:05	Trash on grizzley hopper
15:00	15:06	0:06	2	1	1.7	15:06	15:08	0:02	Trash on grizzley hopper
15:08	15:32	0:24	2	1	1.7	15:32	15:40	0:08	shift to Cut 2, pos 3
		0:00				15:40	15:44	0:04	Fuel Cat 375
15:44	16:22	0:38	2	3	1.7	16:22	16:28	0:06	Shift to Cut 2, pos 4
16:28	16:49	0:21	2	4	1.7	16:49	16:51	0:02	Trash on grizzley hopper
16:51	16:55	0:04	2	4	1.7	16:55	16:57	0:02	Trash on grizzley hopper
16:57	17:01	0:04	2	4	1.7	17:01	17:40	0:39	Shift to Cut 1, pos 1
17:40	18:04	0:24	1	1	3.0	18:04	18:08	0:04	Backwash
18:08	18:29	0:21	1	1	3.0	18:29	18:46	0:17	Backwash
18:46	18:54	0:08	1	1	3.0	18:54	18:59	0:05	Shift to Cut 1, pos 2
18:59	19:04	0:05	1	2	3.0	19:04	19:07	0:03	Shift correction due to failing boat
19:07	19:22	0:15	1	2	3.0	19:22	19:24	0:02	Backwash
19:24	19:45	0:21	1	2	3.0	19:45	19:53	0:08	Backwash
19:53	20:06	0:13	1	2	3.0				
	total:	6:07					total:	4:29	

REMARKS:

Dredge pos. 3 redredged from 1.5' to 2'; after grab sample had shown the bottom not to be clean.
15:45 Support vessel Miami grounded creating turbidity
All day delivery of fuel and water supply with Miami and barge creating local turbidity
Spud position 1 left vertical cut on West side and graded cut on North side

The average cycle time of the 375 LC for this cycle is around 40 seconds for normal digging without environmental operational controls (Caterpillar, 1998). During actual dredging operations, as seen over the course of the PDFT, the excavator cycle time will be affected primarily by the depth of cut, operational controls due to environmental safeguarding, and operator skill. The overall excavator production rate is affected by cycle time, dredge movements and positioning, layer height of the grab, and material hopper capacity. In practice, other delays, including weather, mechanical problems, and logistics can impact excavator production. The average cycle time per grab of the BELLC dredge as recorded on the day with the greatest production (August 17), was 120 seconds. Excavator production calculations are based on the volume of material dredged as defined by the variance between pre- and post-dredge surveys and the net operational (effective) hours of the excavator between those surveys. Excavator production for the PDFT has been calculated for each day and expressed in cubic yards per net operational (effective) hour. During the initial days of trial dredging, August 11-13, no significant, representative running time was achieved due to system debugging and operator learning, and post-dredge surveys were not completed. Post-dredge progress surveys, performed for the purposes of assessing dredging accuracy and dredge production began on Monday, August 14, 2000.

The total volume of material dredged between August 14 and August 18, as determined by comparison of pre-dredge and post-dredge hydrographic surveys was 2,308 cy. The average hourly production rate for the excavator *alone* over this period was 80.3 cubic yards per hour (cy/hr.). On the final day of dredging, August 18, the excavator production averaged 106.1 cy/hr. The processes affecting the overall dredge production are discussed below.

Dredge Movements and Positioning

Dredge cuts within the PDFT area were set at 30 ft. wide x 100 ft. long. The width of the dredge cut corresponded to the width of the moonpool. As the total width of the moonpool was 40 ft., extra space was available for completing to required depth (grade) an adjacent cut while set over the subject cut, or to allow the dredge some freedom of movement relative to the dredge cut. One dredge cut consisted of four barge- or "spud" positions, as dictated by the 30 ft. length of the moonpool. "Shifting" of the barge was guided with the aid of a gyrocompass repeater and the computer display of the CMS. The CMS provided the operator and the SPU operator a heads-up display, in real time of the dredge in relation to the dredge area. During dredge shifting, a smaller scale on the monitor of the CMS computer system was selected to obtain a plan view image of the dredge in relation to the target dredge cut. Shifting between spud positions within a dredge cut was accomplished by lifting the spuds alternatively and pivoting the barge with one of the winches. A shifting pattern was developed by BELLC for the test dredge that permitted the dredge to remain on line with the dredge cut. The shifting pattern of the BELLC Test Dredge was somewhat unconventional due to the wide barge width relative to the barge length. The shifting patterns used to keep the dredge in line while shifting are presented in Appendix D. The actual shifting patterns employed to move the dredge between spud positions during the PDFT were observed to vary depending on the desired dredge orientation position relative to adjacent cuts (i.e., pickup material in adjacent cuts).

The position of the BELLC dredge while in the PDFT area was maintained by two spuds located on either side of the dredge. The spuds were lifted by means of hydraulic driven winches. To provide barge propulsion during shifting, four 500-lb. anchors were set. Where bottom material was too soft to permit good anchoring, as is the case along the western side of the Upper Harbor, the techniques of using either dual anchors, or land anchors were employed. Two (2) two-drum diesel anchor winches were installed on each side of the barge and used to pay in and pay out wire rope to advance the dredge into the dredge cut. Shifting from one dredge cut to another or outside the dredge area (to allow for surveys) was accomplished by lifting both spuds with anchor winches. Where the anchors could not support a full shifting load, or when the dredge would move over distances outside the anchor setup, the dredge tender

"Miami II" was used to provide propulsion. When the dredge was positioned in a new area, the anchors would be reset and the dredge would have a range within which to move.

The time required to make a shift (spud position change) was measured to take between 6 and 10 minutes. Dredge advance time and alignment became better with crew and dredge operator practice. The time required to move the dredge out of the cut depended on a number of factors, most significant of which was the available stopping force of the anchor. If the anchor slipped at all, the dredge had significantly less control of it's advance movement, and would require a reset of the anchor and/or vessel assist for propulsion into the next cut. It should also be pointed out that for the PDFT, short (100 ft.) cutting lanes were established, relative to the lanes that would be established on the full scale project. Longer lanes would translate into less anchor setting, higher productions and cleaner bottom surfaces. The full scale dredge plan would attempt to achieve cut lanes of up to 500 ft. in length or more.

Depth of Cut

An important element directly influencing the production of the excavator is the depth of cut to be removed. The depth of cut is alternately called the layer thickness or bank height. In the PDFT test area the depth of cut ranged from 1.7 ft. to 4.0 ft. Excavating a thicker layer means that more volume can be dredged before the dredge has to be shifted to a new position, and subsequently, less time is lost for shifting per volume of dredged material. Full bucket grabs also translates into higher production, whereby delivery of as much material as possible is accomplished with minimal entrapment of water.

Operation of the BELLC dredge in environmental (accurate) dredging mode, involved importing DTM data showing the bathymetry of the test area bottom surface, with the dredge plan showing area and vertical extent of cuts, in the dredge's CMS. The dredge plan was based on the results of the PCB characterization and input from USACE, Foster Wheeler, and BELLC as to the aerial extent and depth of cut. The bottom elevation of the cut was defined as depth of cut beneath the bottom surface, calculated by subtracting the depth of cut from the bathymetry. This target elevation was also shown in the CMS, for dredge operator guidance.

The bank height (depth of cut) that provided a full bucket for the 4.5 cy HPG bucket was 14 in. For the PDFT however, and likely for the full scale project, removal of layers of a height less than that which would provide a full bucket was instituted to reduce spillage of material. A layer height of 12 in. was targeted by BELLC to achieve good production with minimal spill, and avoid development of windrows, and to minimize impacts to water quality. A layer height of 12 in. provides a bucket that is approximately 75% full. A 100% bucket fill may cause the squeezing out of material and leave windrows on the bottom surface. An initial minimal overdepth (3-4 in.), was taken into account, as the goal was to deliver a “clean” bottom, to provide for inaccuracies in the different steps of the removal process, namely core sampling, surveying and dredging.

During dredging along the boundaries of a cut, step cuts, which provide a means of creating a slope by dredging a “stairstep”, were made to avoid vertical walls of greater than 1 foot height, which might collapse or erode easily. Dredging was initially made in Cuts 6, 7, 8, and 5, respectively as close as possible to the target dredge level, using the dredge plan. Once it was realized that a native, uncontaminated clay layer was not as thick as that indicated in the sediment characterization plots, possibly due to smearing in the core tube, the dredge level in dredge Cuts 2, 3 and 4 changed from one based on the theoretical plan to one based on observation. When the operator encountered clay, as evidenced by deposition on the material hopper grizzly, dredging proceeded no deeper in that grab position. Where the clay layer occurred at more than a few inches from the planned theoretical dredge level, the target level was adjusted within tenths of a foot of the visual observation on the next, adjacent spud or “moonpool” position (1/4 of a dredge cut), in an attempt to minimize the removal of the underlying clay, which had been tested in the laboratory to be "clean". This visual observation method of determining dredge depth was applied in Cuts 2, 3 and 4. In these cuts, the depth of cut was reduced from a planned 2 ft. cut, to a 1.7 ft. and 1.8 ft. cut. This visual technique of dredging did not appear to impact production, so long as the crane operator was given clear and quick instruction on the "new" dredge elevation, by means of rapid update of the CMS, a process that was observed on the BELLC dredge. The dredging accuracy and PCB removal efficiency results of the PDFT, including in Cuts 2, 3, and 4, appeared good, and are presented in Sections 3.1.2 and 4.2, respectively.

To assess the dredge production as a function of depth of cut (bank height), productions were evaluated for the period August 15-17, a period over which the excavator production varied between 60 cy/hr and 85 cy/hr. During this period the depth of cut, that is the layer height to be removed within a cut, ranged between 1.7 ft. and 2.0 ft. On August 18, dredging in Cuts 1 and A, where the depth of cut was between 3 ft. and 4 ft., the excavator production increased to 106 cy/hr.

Sediment Type

The type of sediment dredged over the course of the PDFT did not appear to impact excavator production one way or the other. In either soft black silt, sand, shell, or clay, the HPG bucket had no problems removing the material. Delays due to material type were encountered on the SPU end of the process as discussed below.

Water Depth

Excavator production will decrease with increasing water depth by the amount of time required to lower and raise the bucket from the bottom. The lowering and retrieving rate of the bucket is a function of the machine selected to operate the bucket, and even more importantly, any operational controls that may be instituted to slow the rate of descent and retrieval in order to maintain air and/or water quality standards.

The production of the BELLC dredge developed and mobilized to the site was limited by draft to work in areas generally deeper than 4 ft. The average draft of the dredge, with fully loaded hopper and fuel tanks was calculated to be approximately 2.5 ft. and was measured to vary between 2 ft. and 4 ft. depending on where along the barge the draft measurements were taken and the level of dredged material in the hopper. As most of the dredge system weight was located at the port forward corner of the dredge, centered on the material hopper, the draft was greatest at this corner of the dredge.

In general the dredge was observed to list forward and to port during all dredging operations. It is believed that with more involved design of the dredge system for a project of greater magnitude than the field test, a barge platform could be constructed with lighter equipment and greater footprint that would float level and draw significantly less water, perhaps 2 ft. or less.

3.1.2 Positioning and Dredging Accuracy

Key to the success of the New Bedford Harbor full-scale remediation will be the ability of the selected dredge(s) to minimize the amount of overdepth dredging while still attaining the target cleanup goals of the project. The BELLC hydraulic excavator dredge was selected for pilot testing, in part, to demonstrate that a mechanical bucket operated from an excavator with rigid connections and state-of-the-art positioning could achieve dredging accuracy exceeding 6 in. in the vertical plane and 24 in. in the horizontal plane.

Real Time Kinematic Positioning (RTK)

An RTK positioning system (Sercel Aquarius RTK) was used to provide the horizontal and vertical positioning for the CMS. At the Sawyer Street Site an RTK differential station was installed to provide the RTK Mobile receiver with the necessary corrections to obtain the required precision.

Horizontal and vertical control was established, for both dredging and surveys, by use of Bench Mark “J ” provided by the USACE. The Massachusetts State Plane coordinates for Benchmark “J” are 2,701,124.58 Northing and 814,466.42 Easting, which is located near the Coggeshall Street Bridge in the Upper Harbor. Before starting the PDFT, four (4) hours of position data logging was carried out on the benchmark with this RTK system to confirm vertical control accuracy. The results are shown in Appendix G, Figure G-1.

Crane Monitoring System (CMS)

The CMS requires several input parameters that are measured by a number of sensors. A schematic drawing showing the CMS input parameters is provided in Figure 3-3. The CMS combines signals from the excavator boom, stick, and bucket hinges, signals from the swing of the excavator, the horizontal and vertical position of the RTK antenna, and the list, trim and orientation of the barge. The precise installation and calibration of these sensors determine the accuracy of the CMS. Each sensor was calibrated before installation on the BELLC test dredge. After installation of all the equipment a field calibration was executed. Horizontal and vertical control of the CMS systems was confirmed daily while the test dredging was underway.

Dredge Positioning

Dredge positioning was established using the CMS with input from the RTK system. The CMS, through use of a heads up computer display terminal, provides the crane operator excellent control of the bucket while dredging, showing where the bucket is in both horizontal and vertical planes, in real time. The CMS display monitors were also provided in the control room and the visitor's room during the PDFT. Figure 2-5 shows the typical CMS screen in the operator’s cab.

Use of the CMS system allowed the crane operator or “leverman” the ability to “see” where the bucket was in relation to the dredge cut, vertically and horizontally. In general what was seen on the screen, that is the depth of cut attained by the operator, was generally within 2-4 in. of the actual depth of cut as determined by the daily progress hydrographic surveys. The CMS also provided the operator the ability to see where he had dredged in the horizontal plane, and was able to minimize searching for the next dredge cut.

The CMS was also used effectively for shifting the dredge into the next spud position. Generally, the SPU operator would direct the barge movements from the SPU control room, the highest point on the dredge. Before shifting the top-view picture of the barge and dredge area was set to a smaller scale, to provide an overview figure of the barge and the dredge area. The bearing of the barge was indicated by a digital repeater of the gyro compass.

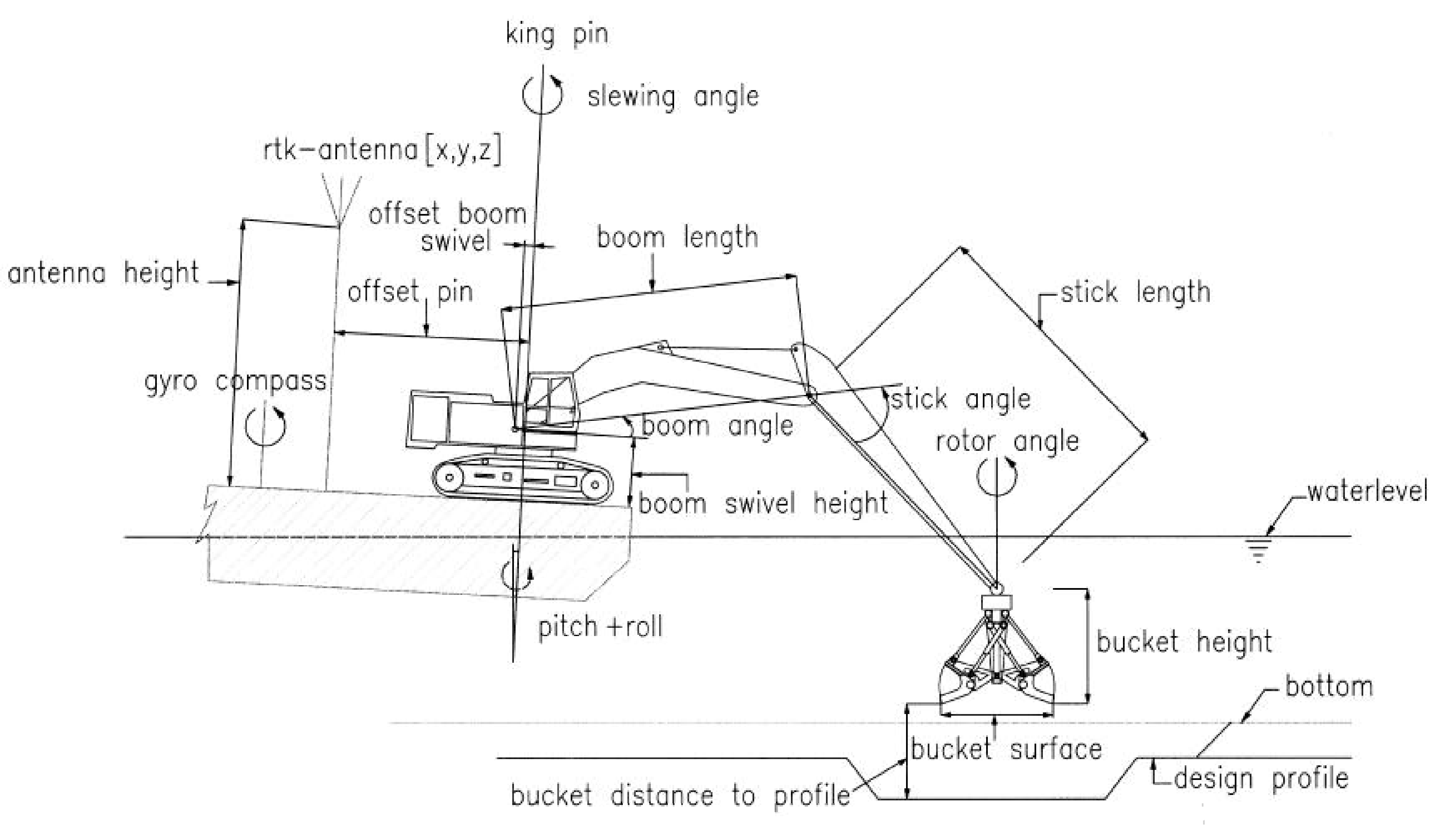

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FIGURE 3-3

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

CRANE MONITORING SYSTEM MEASUREMENTS

NOT TO SCALE

CAD FILE: NBH_IMAGE-1.DWG

Hydrographic Surveys

The dredging process was monitored by hydrographic surveys. USACE Class 1 Hydrographic survey methods were employed to ensure optimal survey system accuracy. The USACE Class 1 Hydrographic Method requires survey accuracy of better than +/- 2 ft. horizontally and +/- 0.5 ft. vertically. The error (accuracy) of the positioning system used by BELLC in the dredge accuracy evaluation, as demonstrated in system calibration routines (Appendix G, Figure G-1) was +.1/-.08 ft. vertically and +.26/-.1 ft. horizontally. The horizontal positioning of the echosounder transducer was defined by means of a Trimble DGPS system. The DGPS antenna on board the survey boat was mounted vertically above the echosounder transducer. For vertical positioning a benchmark near the office site was created and a tide board close to the dredge area was installed. Before every survey a bar-check to calibrate the echosounder and a position check were carried out. During surveys tide readings were registered and used for post processing of the survey data.

Survey Results

All survey data was post processed and incorporated into a DTM to compare various survey surfaces and design surfaces, and generate cross sections of the dredge cut area.

During analyses of the survey results by BELLC it appeared that the horizontal position data recorded over the course of the survey program had a systematic time delay of approximately 0.4 seconds in comparison with the recorded depth data. The final post-dredge survey results reflect the correction to this time delay. A final confirmatory post-dredge survey of the PDFT test area was also conducted by the USACE and showed good agreement with the BELLC survey.

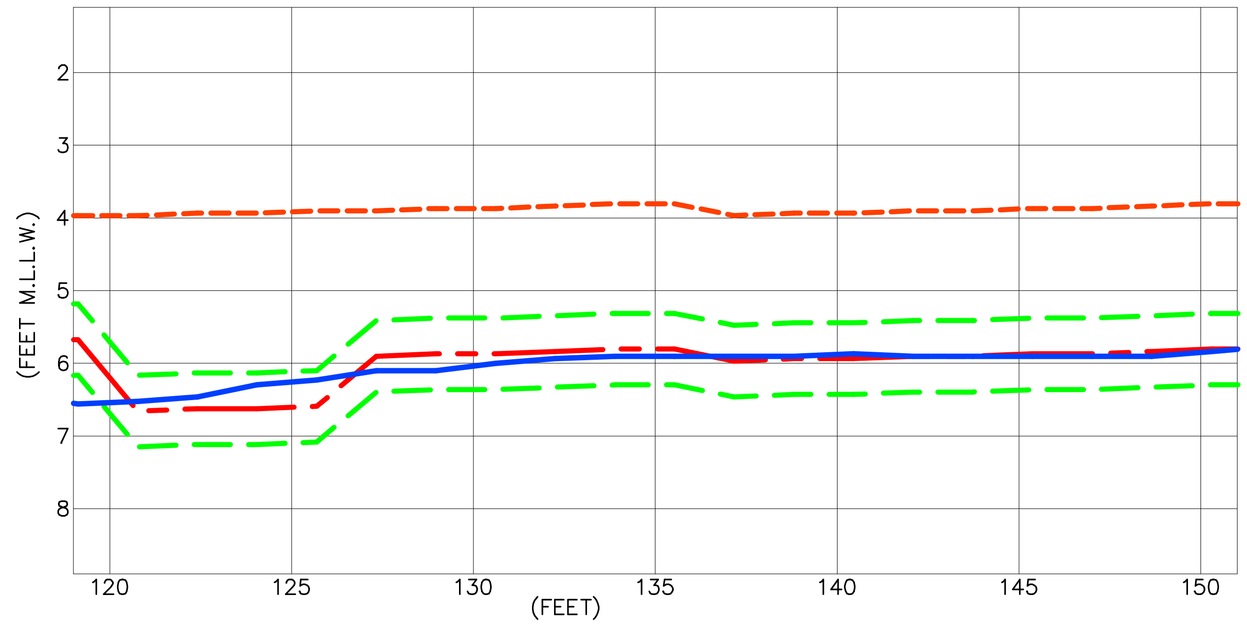
The entire set of hydrographic survey results across the PDFT test area are presented in Appendix H. Only surveys of Cuts 5, 6, 7 and 8, where the focus of the PDFT was dredging accuracy to the target depth, were used for the purposes of assessing the dredging accuracy performance of the BELLC dredge.

Dredging Accuracy

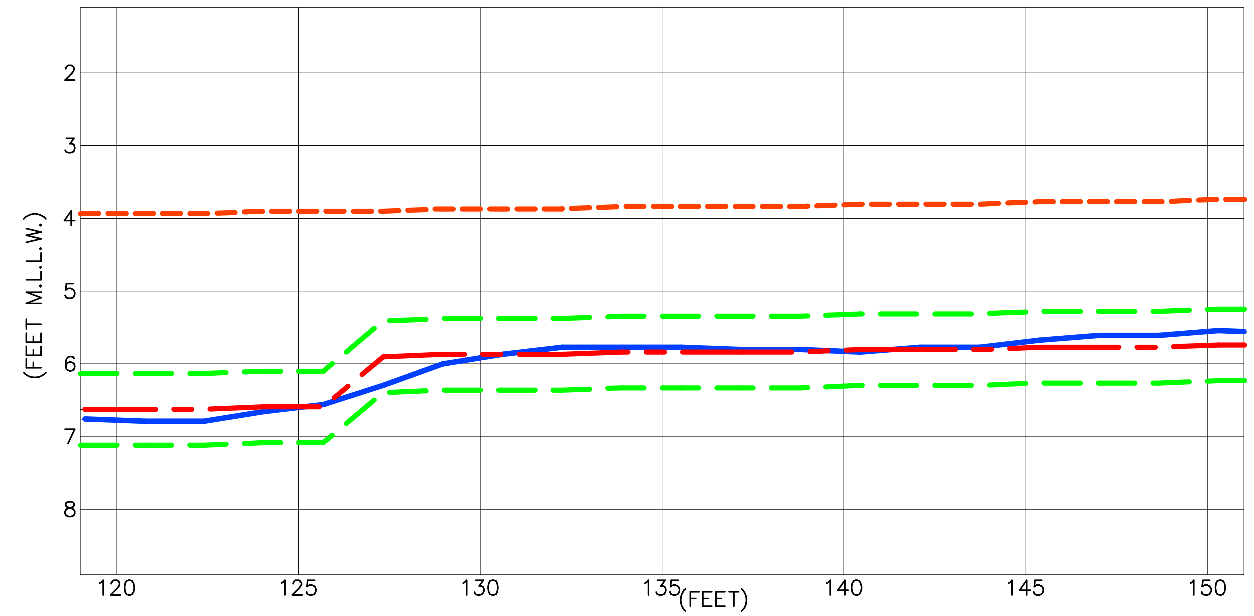
Figures 3-4 through 3-7 show the pre- and post- dredge survey and target elevation cross sections for Cuts 5, 6, 7 and 8 used to evaluate the accuracy of the BELLC test dredge. Additional survey data generated for the PDFT is provided in Appendix H.

As can be seen from the cross sections in particular, the dredge performed very well in terms of vertical dredging accuracy. Overall a +/- 3-inch vertical dredging accuracy was demonstrated across Cuts 5, 6, 7, and 8. A +/- 4-inch vertical dredging accuracy was demonstrated across the entire PDFT test area by the BELLC dredge.

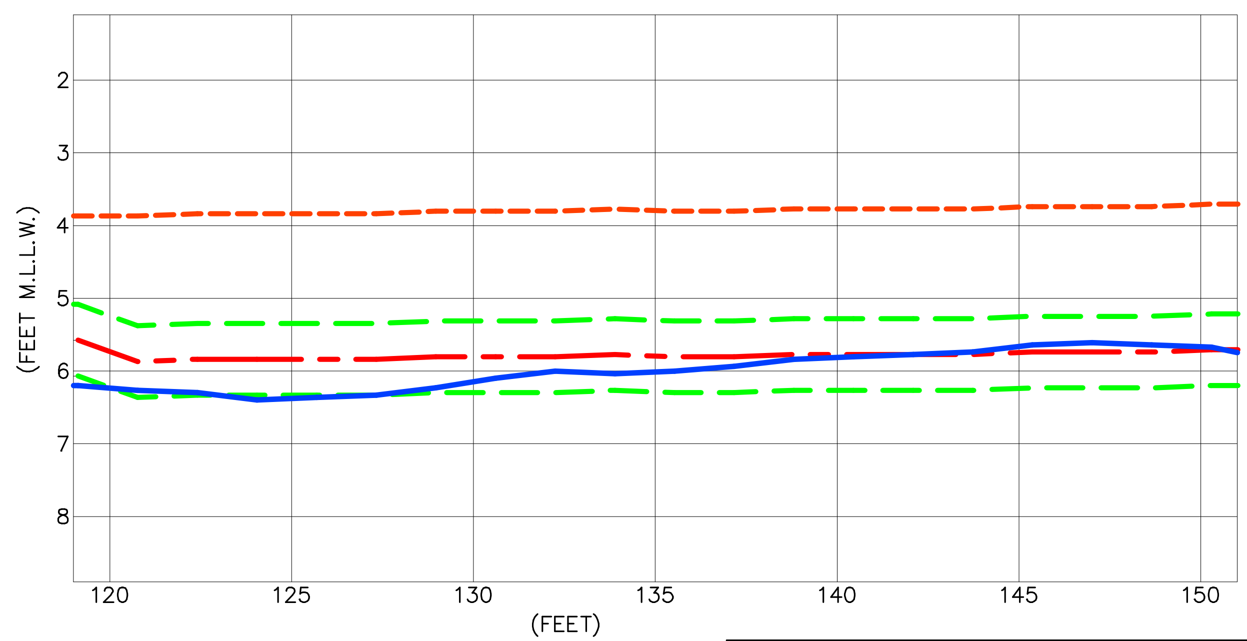
Additional accuracy evaluation was carried out by BELLC which was based on comparison of the post-dredge survey with the target depths for Cuts 6, 7 and 8. The DTM compared 700 points across the 30 ft. x 110 ft. cut area. The % occurrence histograms showing that 95 % of the data points are within 6 in. of the target depth, and 90% are within 4 in. Most of the points that deviate more than 6 in. are in the slope area, on the north and south ends of the cut. The results of BELLCs accuracy evaluation are provided in Appendix G.



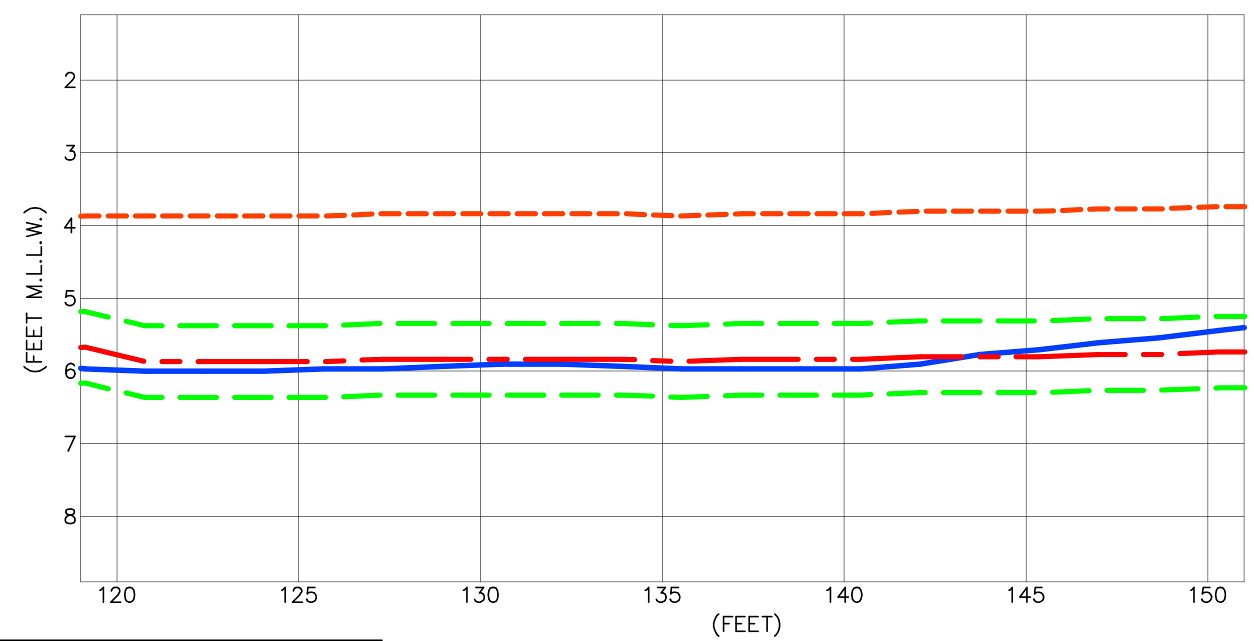
CUT 5 STATION 20



CUT 5 STATION 40



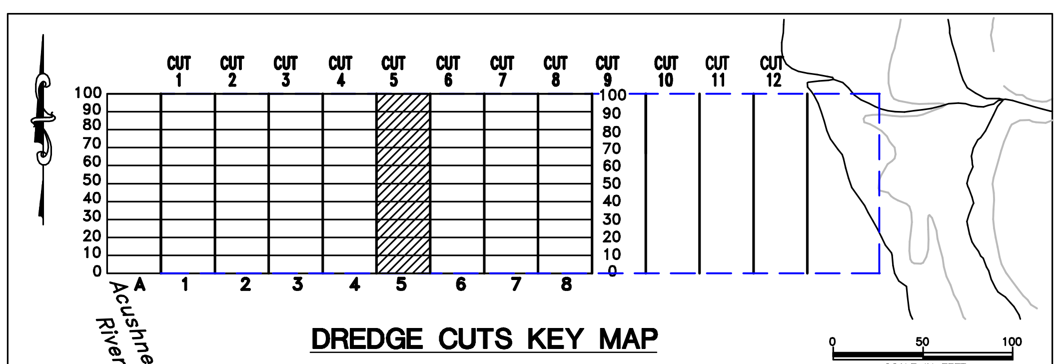
CUT 5 STATION 60



CUT 5 STATION 80

LEGEND

- Pre dredge survey 08/05/00
- Post dredge survey 08/19/00
- Target depth
- Target depth +/− 6 inches



DREDGE CUTS KEY MAP

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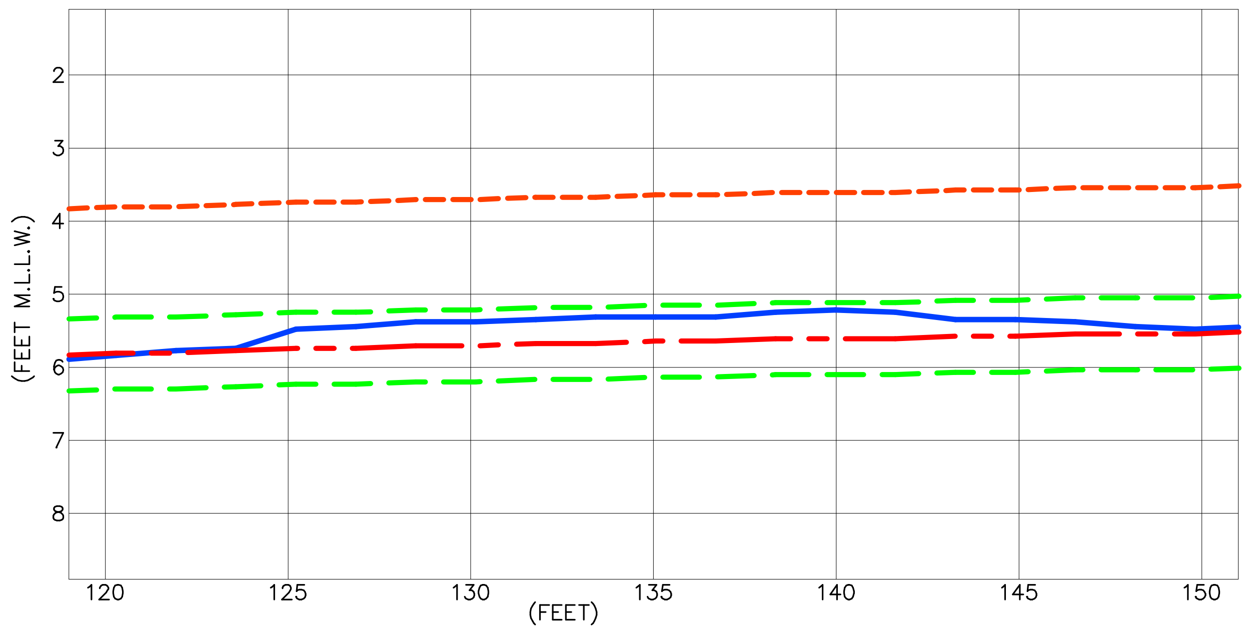
FIGURE 3-4

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

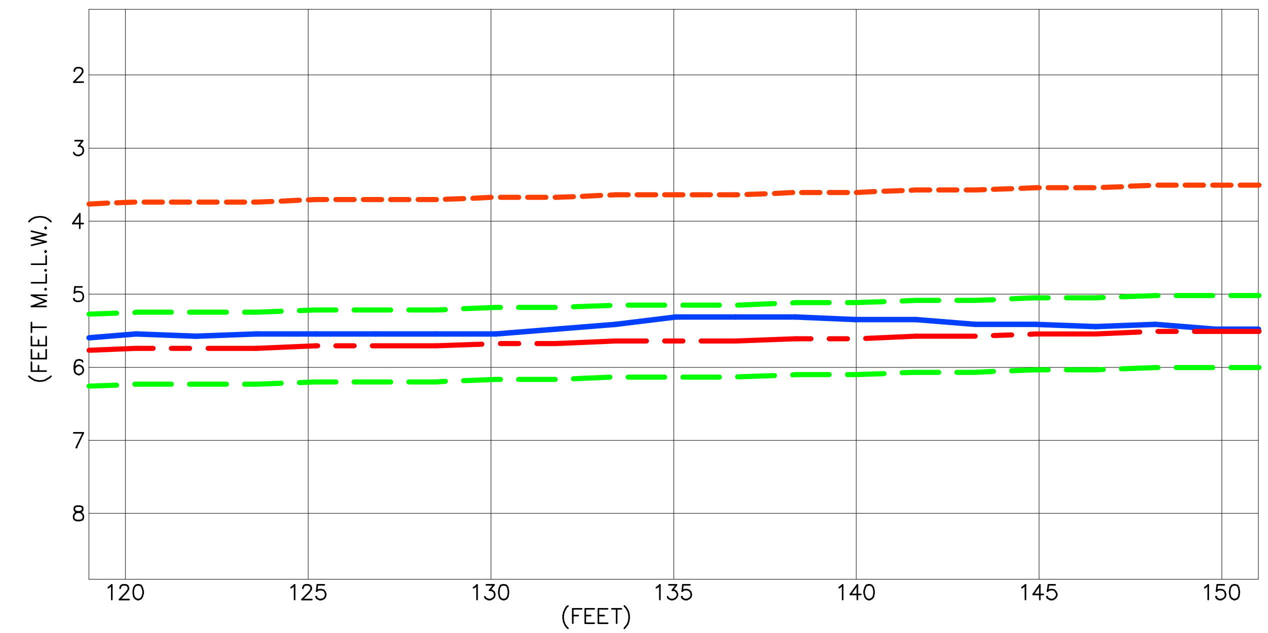
CUT 5
CROSS SECTIONS

SCALE: AS SHOWN

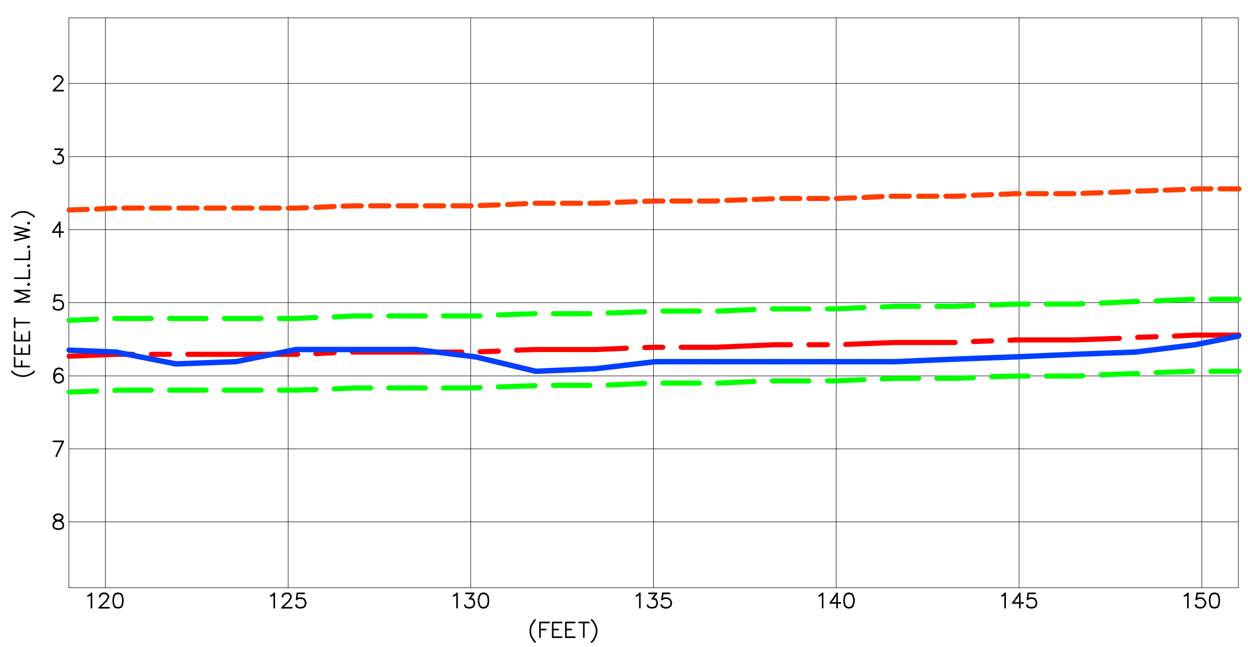
CAD FILE: MNBETS03-1A.DWG



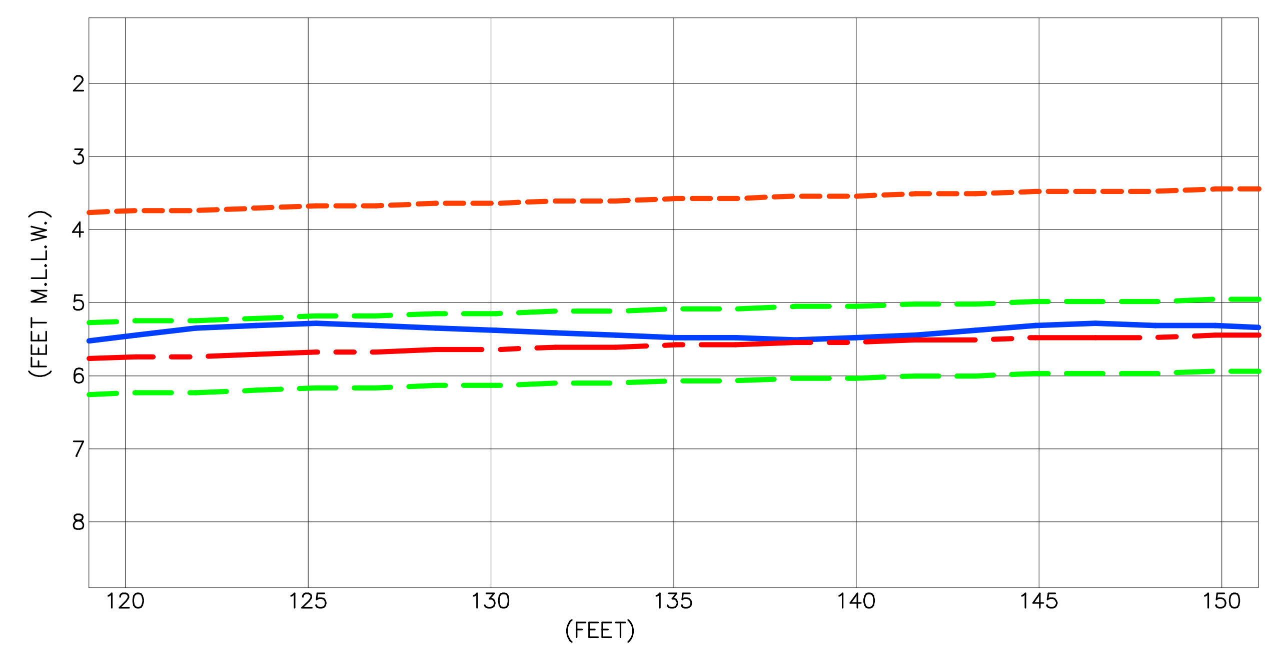
CUT 6 STATION 20



CUT 6 STATION 40



CUT 6 STATION 60



CUT 6 STATION 80

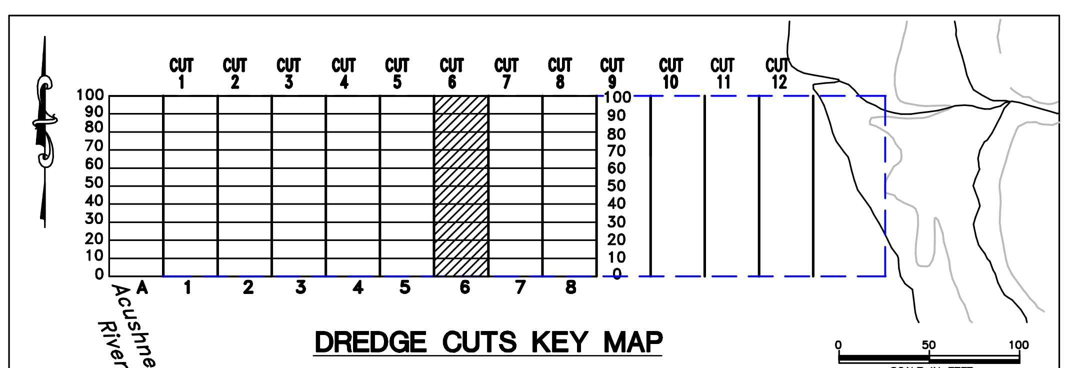
LEGEND

Pre dredge survey 08/05/00

Post dredge survey 08/19/00

Target depth

Target depth +/– 6 inches



DREDGE CUTS KEY MAP

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FIGURE 3-5

NEW BEDFORD HARBOR SUPERFUND SITE
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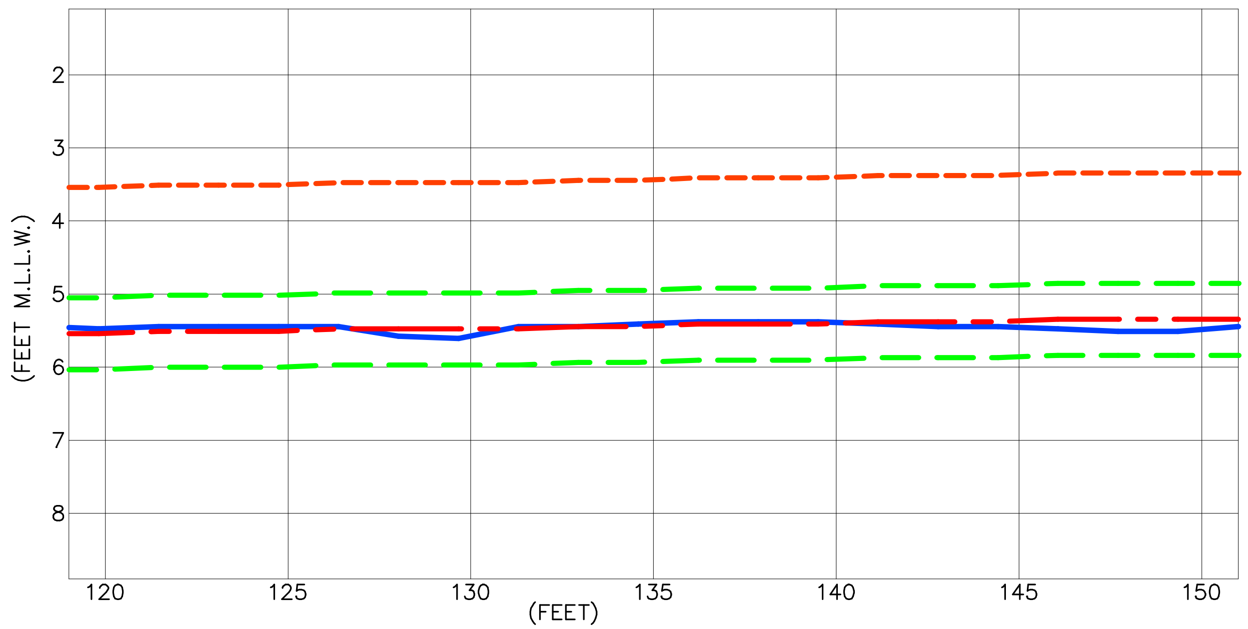
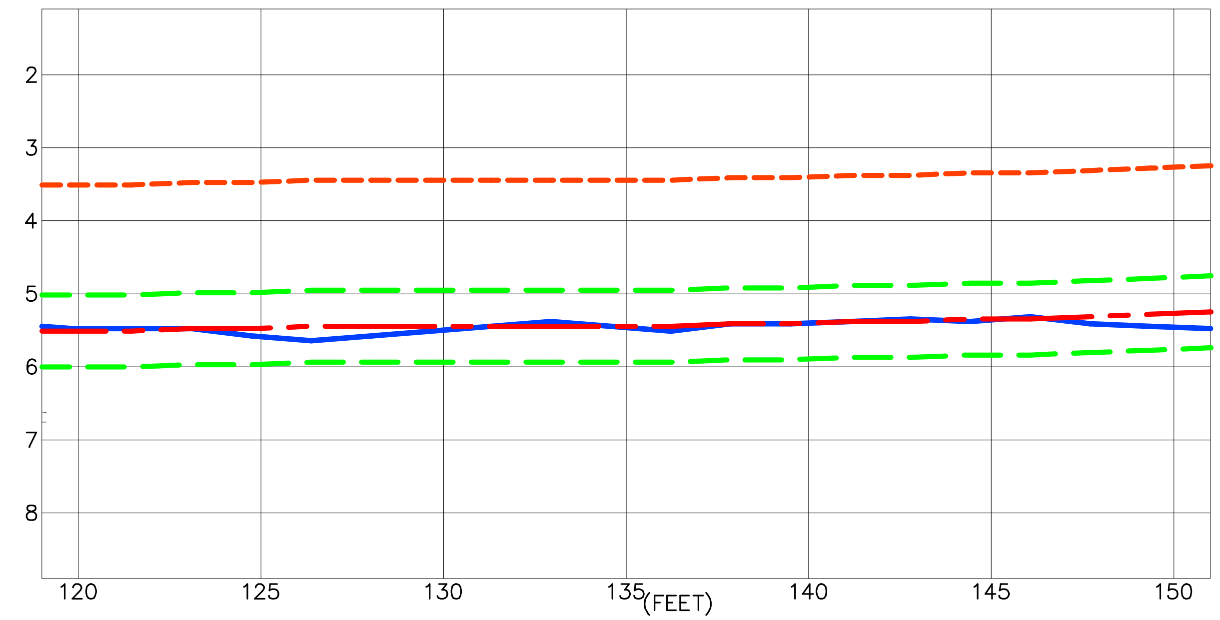
CUT 6
CROSS SECTIONS

SCALE: AS SHOWN

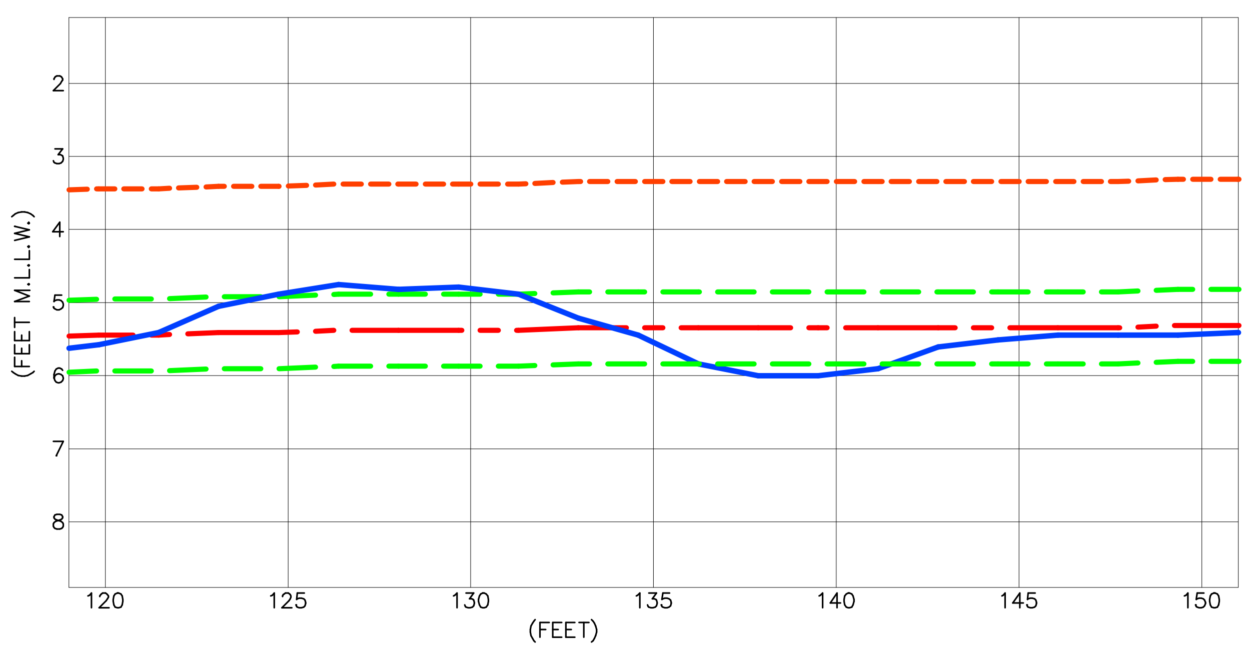
CAD FILE: MNBETS06–1A.DWG



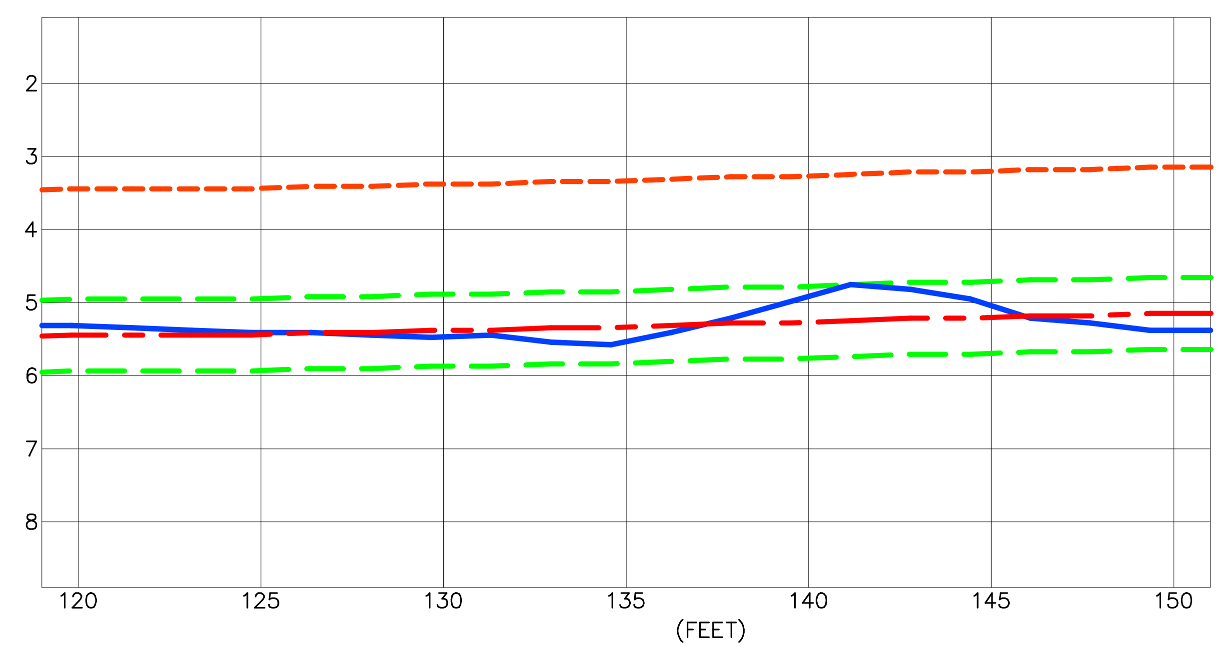
CUT 7 STATION 20



CUT 7 STATION 40



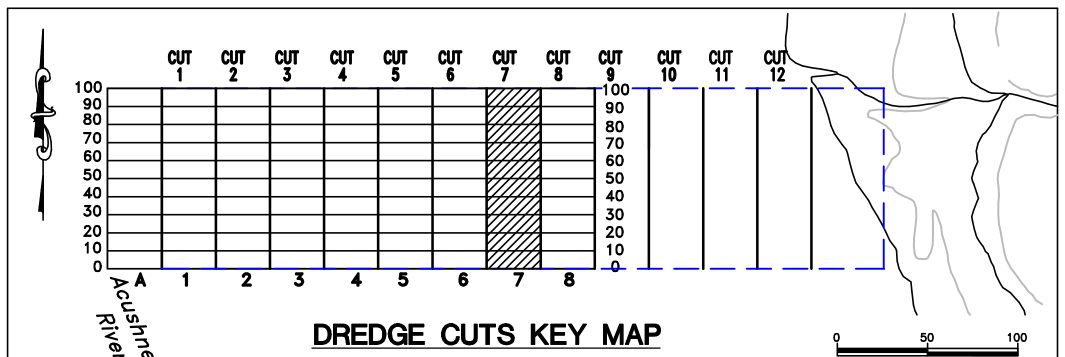
CUT 7 STATION 60



CUT 7 STATION 80

LEGEND

- Pre dredge survey 08/05/00
- Post dredge survey 08/19/00
- Target depth
- Target depth +/− 6 inches



DREDGE CUTS KEY MAP

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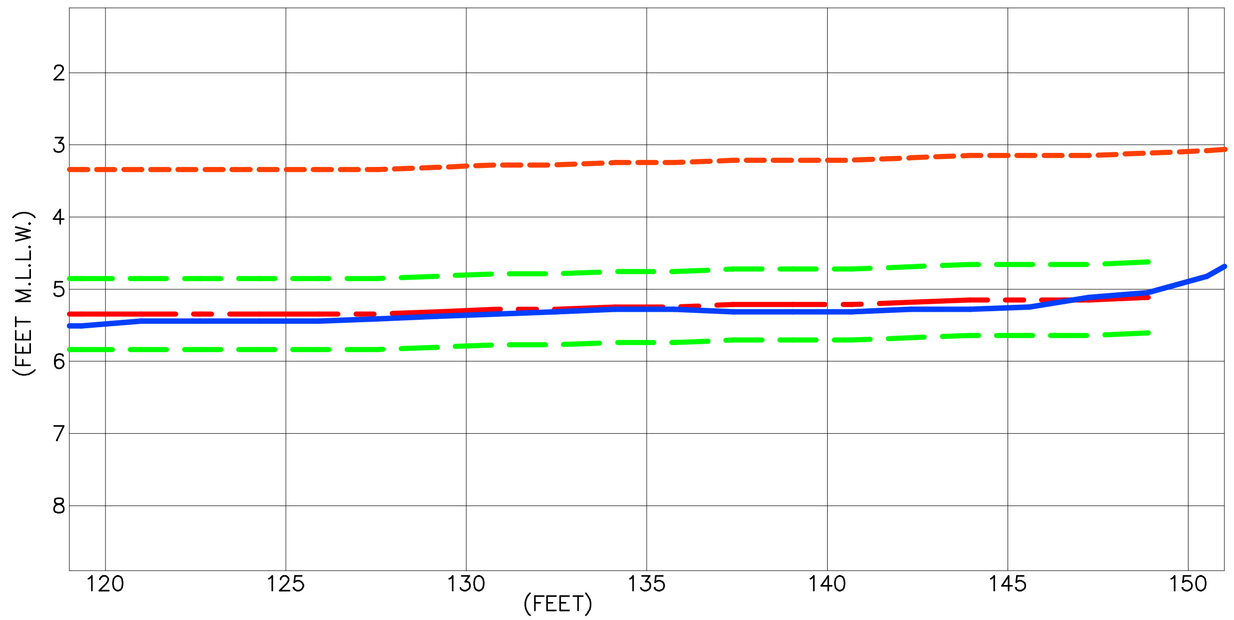
FIGURE 3-6

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

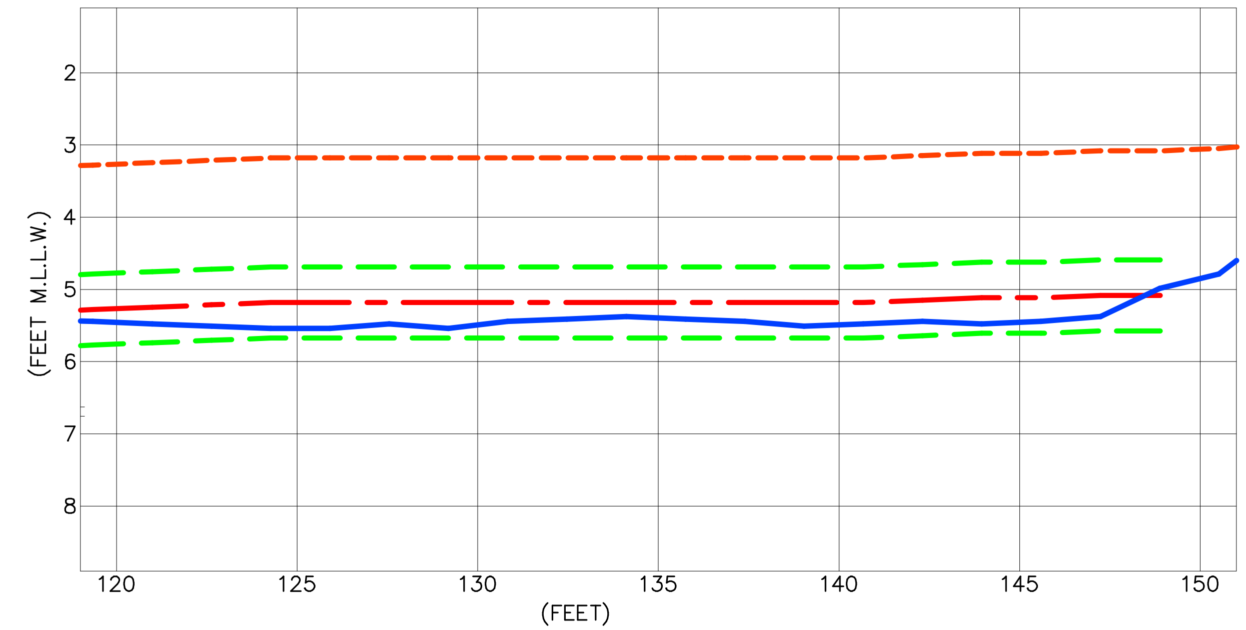
CUT 7
CROSS SECTIONS

SCALE: AS SHOWN

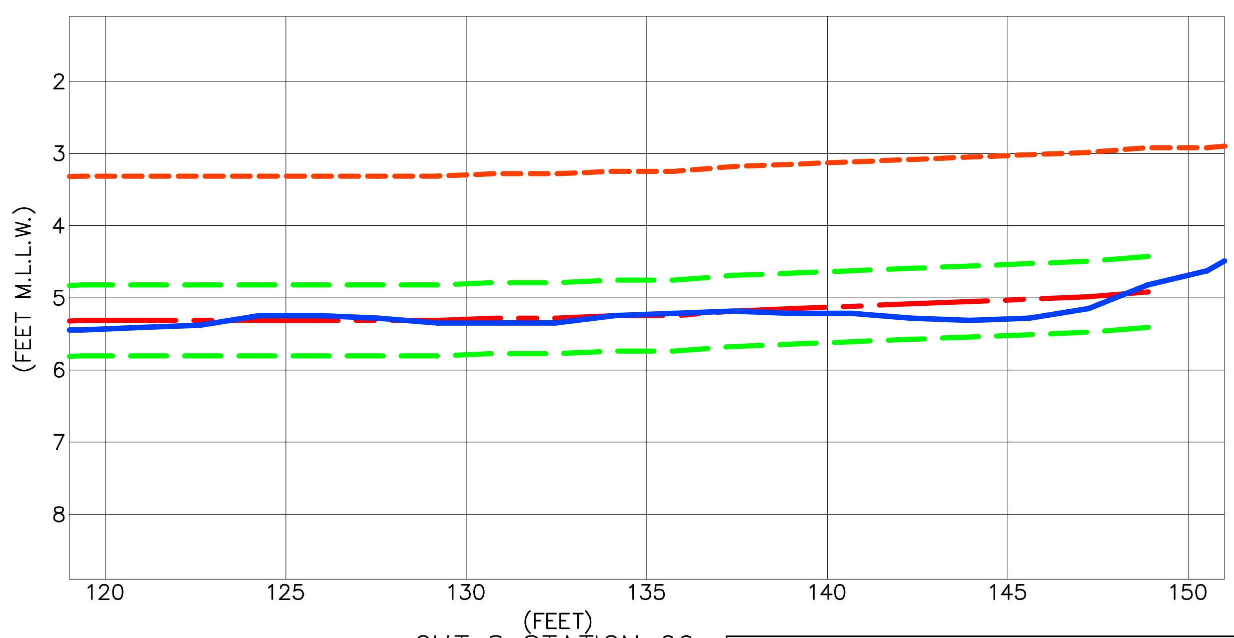
CAD FILE: MNBETS09-1A.DWG



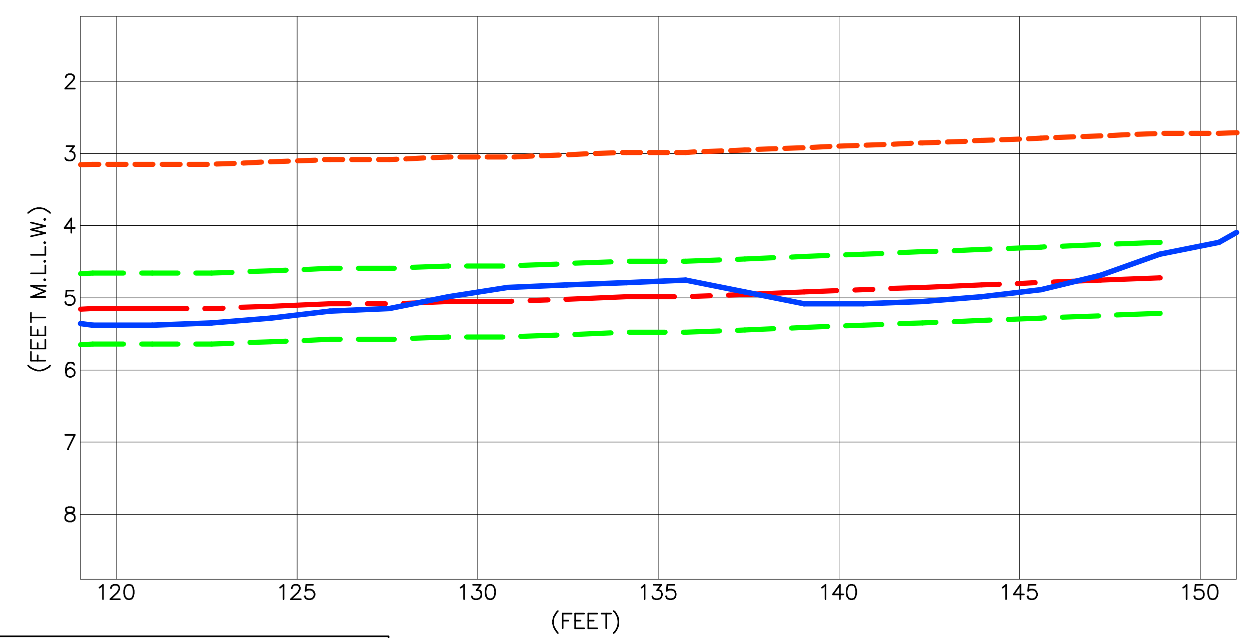
CUT 8 STATION 20



CUT 8 STATION 40



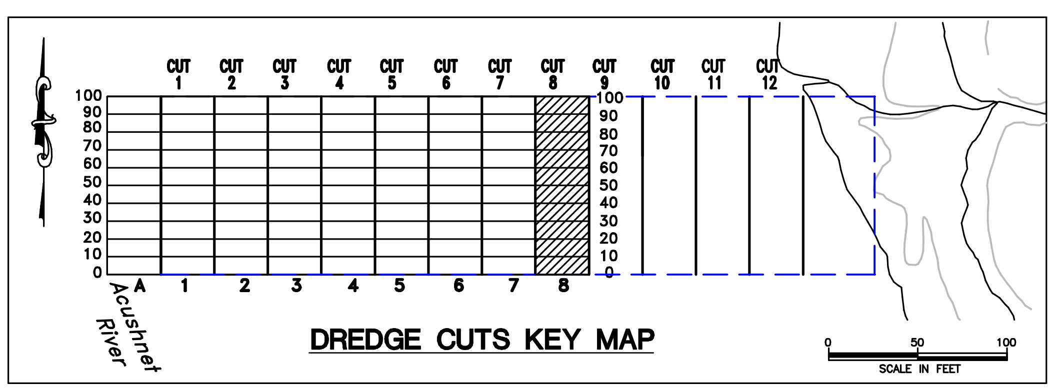
CUT 8 STATION 60



CUT 8 STATION 80

LEGEND

- Pre dredge survey 08/05/00
- Post dredge survey 08/19/00
- Target depth
- Target depth +/− 6 inches



DREDGE CUTS KEY MAP

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FIGURE 3-7

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

CUT 8
CROSS SECTIONS

SCALE: AS SHOWN

CAD FILE: MNBETS12-1A.DWG

Correlation with PCB Removal Efficiency

Section 4.2 of this report evaluates the PCB removal efficiency of the BELLC dredge. Comparison of the pre- and post-dredge PCB concentration in the sediment within the test area indicated that approximately 97% of the PCB mass was removed from the test area during the PDFT.

After dredging Cuts 6, 7, 8, and 5, in that order, it was realized in the field that a "clean" clay layer was oftentimes higher in elevation than that shown in contamination characterization plots. Thereafter, with concurrence from the PDFT team, the field target dredge level in Cuts 2, 3 and 4 changed from one based on the theoretical plan to one based on observation. When the operator encountered clay, as evidenced by deposition on the material hopper grizzly, dredging proceeded no deeper in that grab position. Where the clay layer occurred at more than a few inches from the planned theoretical dredge level, the target level was adjusted within tenths of a foot of the visual observation on the next, adjacent spud or "moonpool" position (1/4 of a dredge cut), in an attempt to minimize the removal of the underlying clay.

This visual observation method of determining dredge depth was applied in Cuts 2, 3 and 4. In these cuts, the depth of cut was reduced from a planned 2-ft. cut, to a 1.7-ft. (Cuts 2, 3 and 4) and 1.8 ft. cut (Cut 4). In these areas, the vertical dredging accuracy decreased to an average of approximately +/- 6 in. from the target. This reduction in accuracy was observed to be a result of interruptions in the CMS system display to the operator, and personnel communication errors. It is therefore reasonable to assume, that with rapid updating of the dredge guidance system to reflect field changes in the target elevation based on visual observations of the clean clay layer, the dredging accuracy will approach that achieved in the areas where the target depth is pre-programmed into the crane operators display.

Volume Calculations

Volume calculations were conducted using the daily progress surveys and the pre-dredge survey. The dredged volumes per dredge cut were calculated using the average end area method. Based on these volume calculations, presented in Appendix I, the total volume of *in situ* material removed from the PDFT test area is 2,308 cy. The target volume of material to be removed, based on the final, actual depth of cut targeted across the PDFT area dredged, was calculated to be 1,985 cy. Comparison of this target volume with the actual volume dredged yields an overdredging value of 16%.

3.1.3 Slurry Processing Unit (SPU) Production

Minimization of the amount of water added to the dredged material is a focus area of the PDFT and the design of the full-scale remediation project.

While mechanical excavation delivers dredged material in as close to *in situ* water concentrations as possible, with minimal entrapment of water, the transportation of mechanically dredged material is typically by barge. Due to the shallowness of the Upper Harbor, barges with material capacity to maintain adequate production cannot navigate the upper harbor waters without adversely impacting water quality.

The Bean patented SPU system is a proprietary hydraulic slurry transport system that delivers high percent solids concentrations, by introducing controlled amounts of water to mechanically dredged material. The SPU measures and monitors the *in situ* water content of the material dredged and placed in a hopper, and injects only as much water as is necessary to keep the slurry moving to the treatment and disposal site, at a specified % solids concentration. The *in situ* material conditions dictate the theoretical maximum achievable slurry density. It is not possible to achieve solids concentrations that are higher than that of the *in situ* material.

The dredged material removed from the dredge cut was placed on the grizzly of the material hopper, where it began the debris separation and material transport phases of the dredging process. Debris larger than 6 in. x 6 in. were screened off the surface of the material hopper and placed in the adjacent debris container for ultimate transport and disposal at the Sawyer Street CDF debris disposal area (DDA).

Loading

The SPU production was directly related to the excavator production. To achieve optimum production for the material transport phase of the process using the SPU, the material hopper was to be kept loaded with dredged material (slurry) continuously, to create a buffer of material to be transported. The hopper capacity was 20 cy, therefore the excavator would require approximately 12 minutes to load the hopper, assuming buckets are loaded 75%. During the field test, the hopper was loaded at a rate ranging from approximately 60 cy/hr to 105 cy/hr, depending on the factors discussed in excavator production above, as well as by the efficiency of the debris separation phase at the hopper grizzly.

Debris Separation

Debris with dimensions larger than 4 in. was expected to cause clogging and required clearing in the SPU system during the hydraulic transport, and was therefore removed out of the system at the following locations:

Coarse debris (greater than 8 inches)

A pre-fabricated 6-inch x 6-inch grizzly screen was installed on the top of the hopper. To remove debris from the screen, a mini excavator was installed next to the grizzly to pick-up debris and to deposit it into the trash bin staged next to the hopper. Over the course of dredge testing during the PDFT, material clogging of the grizzly screen was occurring when the gray clay layer was encountered and deposited on the screen. The clay was cohesive and stiff enough that the screen opening would become clogged and not permit the passage of looser material. To remedy this problem, two (2) modifications were made to the mini excavator. First a water jet hose was installed from the water injection manifold, charged with recirculation water, to the end of the mini excavator arm, to be used as an instrument in breaking up the clogged clay. A flat steel plate was also welded onto the backside of the mini excavator bucket, to close the gaps between the bucket teeth, and provide a tool surface which the mini-excavator operator could "mash" the clay through the screen with. Any debris that was separated out by the grizzly, including larger cobbles, metal debris such as chain and wire rope, shopping carts, tires, wood and plastic sheets, was washed with the waterjet, and was deposited into the trash bin, next to the grizzly.

Despite the field remedies implemented to streamline the debris separation phase, some delay was caused by the inability of the grizzly screen to pass dredged material into the hopper such that hopper capacity was not sufficient to continue the hydraulic transport process. For a full scale dredging operation it was suggested by BELLC that, based on site conditions encountered, a different type of debris separation system, such as a vibrating screen, or rotating drum screen, may provide more efficient results.

Figure 3-8
Clearing Rockbox of Debris, note cobbles at base of Rockbox

Small debris (less than 4 inches)

As the inside diameter of the discharge line was 7.13 in., another debris collector, termed the "rockbox", with a screen mesh of 4 in. was installed in the suction line between the hopper bottom and the slurry pump. A significant amount of smaller debris caused the frequent clogging of the screen in the rockbox. The debris consisted of smaller cobbles, plastic debris, horseshoe crabs and a significant amount of quahogs. After some significant downtime and impacts to the overall dredge production due to clogging of the rockbox by this smaller debris, the ultimate remedy for maintaining a clear rockbox was the installation of two additional high pressure water jets, again using recirculation water, on either side of the rock box. Additionally, by experience, the clogging could be avoided by declutching the dredge pump and backflushing the screen of the rockbox periodically. While this preventative measure did reduce the SPU production by a small amount, it was a lesser amount than that attributable to the shutdown of the system to open and clear the rock box and/or pump, a process that took between 24 to 51 minutes, depending on a number of factors, namely volume and type of debris clogging the suction line. Despite delays due to debris on the hydraulic transport process, the excavator production generally could continue most of the time due to the buffering capacity of the hopper.

One significant downtime event did occur however due to debris. On Saturday August 12, at approximately 12:20 hrs., the dredge encountered suction pressure problems on the SPU. It was not known whether this was a problem caused by debris clogging, poor pump performance or some other reason. After about 12 hrs. of downtime to not only resolve the suction pressure issue, and perform other optimization measures, it was discovered that a ¼-inch thick piece of angle iron, roughly 10 in. long by 5 in. high, had managed to pass through the grizzly screen, through the horizontal augers and become lodged in the suction line between the hopper bottom and the rockbox. Based on the photo taken below, it would appear that the metal was effectively choking the suction pipe by about 80%. The piece of metal was removed, and along with the activation of another suction jet at the base of the hopper, the suction problems encountered until that time were drastically reduced.

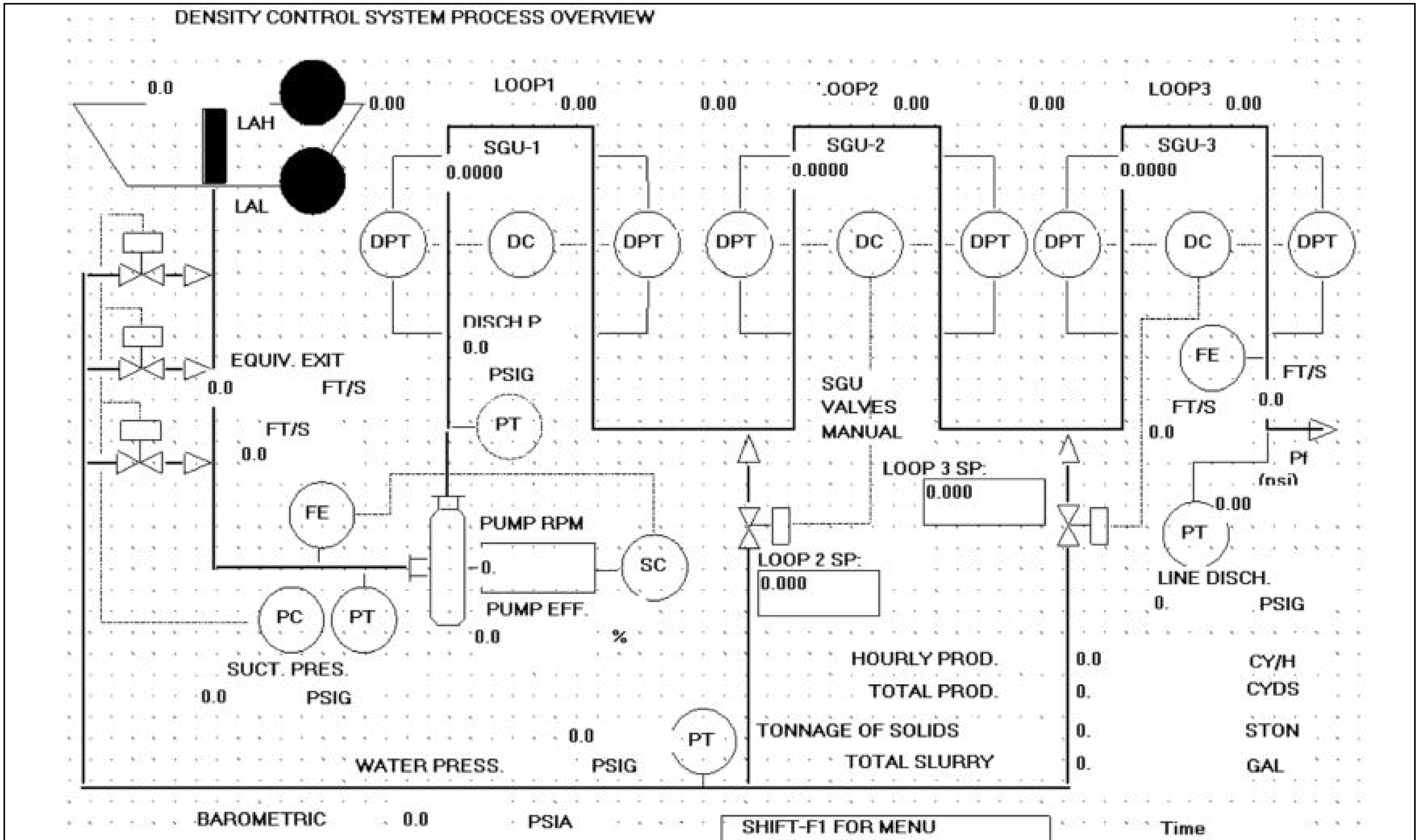
Figure 3-9
Steel Plate Lodged in Suction Line

Figure 3-10
Steel Plate Lodged in Suction Line

Approximately 5 tons of debris, both separated out at the grizzly and the rockbox, were removed from the dredged material prior to pumping to shore. This quantity represents less than 1/10 of 1 percent of the total volume dredged during the PDFT.

The SPU worked properly during the dredge test and appeared to be stable in the automated mode. The SPU controls permitted easy adjustment of the hydraulic transport parameters such as discharge velocity and maximum allowable slurry density. The automated injection of recirculation water at the three supply points appeared to work correctly. All process parameters were observed clearly at the operators desk panel gauges and on the SPU computer monitor. A screen dump of the SPU controls display is presented in Figure 3-11.

The hydraulic transport capacity of the SPU was designed to be higher than the maximum excavator production, to optimize the production potential of the dredge. The design production limit is therefore on the excavator process. As a significant volume of debris between approximately 3 and 6 in. was encountered, the rockbox clogged frequently despite the adaptation of a number of jets intended to break up such clogging. As such, the dredge (SPU) operator was required to add more recirculated water than is typically necessary to move slurry without risking the plugging of the discharge pipe. In adding more water the density of the slurry, and thereby the dredge production, decreases.



FOSTER WHEELER

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133 FEDERAL STREET, BOSTON, MASSACHUSETTS 02110

BEAN ENVIRONMENTAL, L.L.C.
ST. CHARLES AVE., SUITE 500
NEW ORLEANS, LA 70130

FIGURE 3-11

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

SPU CONTROLS DISPLAY

NOT TO SCALE

CAD FILE: NBH_IMAGE-1.DWG

SPU Production

SPU production is based on net operational hours of the SPU and the mass (tons) of dry solids recorded by the SPU system. The net operational hours for the SPU are based on the following selection criteria:

- SG loop 3 >1.040 specific gravity unit (SGU);
- RPM of the slurry pump >700 rpm; and
- Flow velocity in flow tube >1 ft/s.

When any or all of these criteria were not met, the SPU was not considered to be operational. In total, the net operational hours for the SPU correspond with the net operational hours of the excavator.

From the recorded flow velocity and the slurry density measured in the third specific gravity loop together with the specific gravity of the dredged material, the tons of dry solids are calculated. The SPU volumes are calculated on the basis of estimated densities of the *in situ* material based on sediment investigation results, as described in this section. SPU productions will not be the same as the excavator production therefore, which are based on the comparison of a post-dredge survey with a pre-dredge survey. An example of a daily SPU production report, for August 17, is presented in Figure 3-12. Data are presented in metric (upper portion) and English units (lower portion) in Figure 3-12.

The SPU production report provides data summarizing the period of performance of the SPU system while the dredge system is operating effectively. The production report separates out data recorded by the SPU for periods when the slurry has a specific gravity less than 1.040, when the slurry pump is turning at under 700 rpm, or when the flow velocity in the discharge pipe (flow tube) is under 1 ft./sec. Either of these conditions represent the dredge system as not working effectively.

Of interest in the SPU production report, for August 17's testing, the dredge was considered effective for 435 minutes of 559 minutes overall. By the SPU system then, the dredge's efficiency was 77.8%. During this day 2,509 cy of slurry was discharged, of which 537 cy of the slurry was *in situ* sediment moved. The average volume of slurry moved was 346 cy/hr, the average volume of *in situ* material moved was 74 cy/hr. This testing day, August 17, represented the best production day for the test dredge, and provides performance values that could be extrapolated for the full-scale remediation.

SPU Solids Concentration Results

This section summarizes and evaluates the sediment solids concentration data obtained during the PDFT. Sediment concentration data was obtained from the following sources:

- Sediment samples taken from the dredged sediments prior to dredging. This data was used to determine the *in situ* (i.e., in-place prior to dredging) physical properties.

- Measurements of slurry flow rate and slurry wet density in the discharge pipeline from the dredge (measured in "specific gravity loop 3" or "SG Loop 3" of the SPU).

- Volumes in Disposal Cells.

The actual volume of sediment dredged was determined by calculating the difference in volume between the pre-dredge and post-dredge mudline surface as measured by bathymetric surveys.

Figure 3-12
SPU Production Summary, August 17, 2000

Date: August 17 2000

Date: August 17 2000	conditions: rho_mix>1040kg/m3, rpm slurry pump>700 rpm, flow velocity in 250 mm flow tube>1 ft/s									
	water density [kg/m3]	specific gravity [kg/m3]	insitu density [kg/m3]	avg. % solids by weight of insitu material	tons dry solid/insitu volume [TDS/situ m3]					
	1015	2400	1410	49%	0.684					
total effective slurry pumping time [min]	**time period analysed [hr:min:ss]**	**Flow velocity [m/s]**	**slurry volume discharged**	**insitu Production**	**tons dry solid Production [metric tons]**	**% solids by weight loop 1 [%]**	**% solids by weight loop 2 [%]**	**% solids by weight loop 3 [%]**	**% volume concentration loop 3 [%]**	**density loop 3 [kg/m3]**
		average	average [m3/hr]	average[insitu m3/hr]	average [tons/hr]	average	average	average	average	average
total dredge period:	10:26:-19:44	1.5	265	57	39	13.67%	9.47%	13.08%	21.38%	1,099
snapshots:	11:07-11:43	1.2	213	72	49	20.19%	17.54%	19.94%	33.78%	1,148
	11:53-12:22	1.1	203	69	47	19.67%	17.60%	20.03%	33.94%	1,149
	13:55-14:35	1.4	240	61	42	16.56%	11.37%	15.44%	25.46%	1,116
	15:02-15:17	1.4	247	82	56	19.12%	16.14%	19.75%	33.28%	1,146
	16:09-16:23	1.9	332	81	56	17.26%	9.82%	15.04%	24.55%	1,112
	17:45-18:29	1.8	325	78	53	14.63%	9.75%	14.60%	23.91%	1,109
total effective [min]	total gross [min]	max	daily total [m3]	daily total [insitu m3]	daily total [tons]	max	max	max	max	max
435	559	2.1	1919	410	281	33%	31%	33%	60%	1,252

missing: datalog values between 19:44 and 20:06: estimated = 20 m3

Date: August 17 2000	conditions: rho_mix>1040kg/m3, rpm slurry pump>700 rpm, flow velocity in 250 mm flow tube>1 ft/s									
	water density [kg/m3]	specific gravity [kg/m3]	insitu density [kg/m3]	avg. % solids by weight of insitu material	short tons dry solid per insitu volume [TDS/cu-ft]					
	1015	2400	1410	49%	0.021					
total effective slurry pumping time [min]	**time period analysed [hr:min:ss]**	**Flow velocity [ft/s]**	**slurry volume discharged**	**insitu Production**	**tons dry solid Production**	**% solids by weight loop 1 [%]**	**% solids by weight loop 2 [%]**	**% solids by weight loop 3 [%]**	**% volume concentration loop 3 [%]**	**density loop 3 SGU**
		average	average [cy/hr]	average [insitu cy/hr]	average [short tons/hr]	average	average	average	average	average
total dredge period:	10:26-19:44	4.9	346	74	43	13.67%	9.47%	13.08%	21.38%	1.099
snapshots:	11:07-11:43	4.0	279	94	54	20.19%	17.54%	19.94%	33.78%	1.148
	11:53-12:22	3.8	265	90	52	19.67%	17.60%	20.03%	33.94%	1.149
	13:55-14:35	4.5	314	80	46	16.56%	11.37%	15.44%	25.46%	1.116
	15:02-15:17	4.6	323	108	62	19.12%	16.14%	19.75%	33.28%	1.146
	16:09-16:23	6.2	434	107	61	17.26%	9.82%	15.04%	24.55%	1.112
	17:45-18:29	6.0	425	102	59	14.63%	9.75%	14.60%	23.91%	1.109
total effective [min]	total gross [min]	max	daily total [cy]	daily total [insitu cy]	daily total [short tons]	max	max	max	max	max
435	559	7.0	2509	537	309	33%	31%	33%	60%	1.252

missing: datalog values between 19:44 and 20:06: estimated = 27 cy

The concentrations in the disposal cell were estimated using the data from column settling, self-weight consolidation and column consolidation tests performed on New Bedford sediment.

There are several common ways of reporting sediment "concentrations" or density. Each method has certain advantages for engineering design or construction monitoring. In the testing done during the dredge PDFT, different methods were used for (a) pre-dredge core samples analyzed in the geotechnical laboratory, (b) monitoring slurry flow through the dredge SPU during dredging, and (c) post-dredge survey and calculations. For calculating quantities of dredged material moved and for evaluating dredge production, it is necessary to convert between difference measurements and reporting methods.

In general, soil contains solid particles, water in void space between soil particles, and air in void spaces. For saturated sediment, the volume of air is zero. The top portion of Figure 3-13 shows a schematic representation of the solid and fluid that make up sediment. Table 3-1 provides a list of definitions used to discuss the results of the PDFT solids concentration study.

Results of the pre-dredge testing are reported in Appendix B and F as "wet weight" in kilograms per meter^3 (Kg/m^3), which can be converted to slurry specific gravity by dividing by 1.000. The average wet unit weight of sediment dredged each day was determined by calculating a weighted-average of the pre-dredge samples in each days dredge area. As shown in Figure 3-13, the wet weight of the sediment dredged on August 16, 2000 was 1,400 Kg/m^3. The drawing in Block 1 of the figure shows other ratios such as "concentration", "percent solids by weight", "percent solids by volume", and "moisture content". In addition to the ratios, the drawing in Block 1 shows corresponding weights and volumes of solids and pore fluid in one cubic foot of *in situ* sediment.

During dredging, slurry concentration was measured by density gauges in pipe loop 3. The flow rate and density measurements were taken continuously during SPU operation. The tables in Appendix F (Figure 3-12 is SPU Production Tables for August 17, 2000) show the percent solids at different times and also gives the calculated daily average percent solids by weight for each days dredge. The average percent solids by weight for August 16, 2000 was 13.15%. The other corresponding ratios are shown on the drawing in Block 2 of Figure 3-13. The *in situ* sediment dredged on August 16 had a concentration of 668 grams per liter (g/L) and a wet unit weight of 87.4 pounds per cubic foot (pcf) (1,400 Kg/m^3). This corresponds to 27.8 percent solids by weight and a moisture content of 110 percent.

In moving from the *in situ* concentration to the slurry concentration, the dry weight of solids is the same (41.7 pounds). Since both the *in situ* sediment and pipeline slurry are both saturated with pore fluids, the only difference in volume is due to the addition of fluid. Note that the concentration went from 41.7 pcf *in situ* to 9 pcf in the slurry and that the volume increased from 1.0 to 4.63 cubic feet (cf). In the pipeline slurry, the concentration was 144 g/L and had a wet weight of 317 pounds with a volume of 4.63 cf (68.5 pcf or 1,100 Kg/m^3). The dry weight of solids and the corresponding volume of dry solids is constant; therefore, the difference between *in situ* volume and pipeline volume is the amount of water added to make the slurry, which is 3.63 cf per cf of *in situ* sediment.

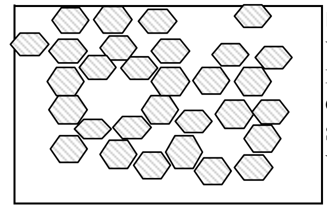
The most accurate method to determine the *in situ* volume of sediment dredged is to perform pre- and post-dredge surveys (which was done for this PDFT). However, dredging contractors need preliminary estimates of *in situ* production during dredging to better manage their work. Therefore, they use data on the flow rate and slurry density combined with data on *in situ* density and concentrations to estimate *in situ* dredge production. The results of typical calculations are shown in Figure 3-12 and the calculations for each day of dredging are shown in Appendix F. The measure values are slurry flow rate, time of discharge and slurry density (also called specific gravity of mixture). This data is used to calculate percent solids in the slurry and dry solids pumped. Finally, data on situ sediment is combined to estimate *in situ* cubic yards of sediment dredged and *in situ* production.

Figure 3-13
Sediment Volume Changes: *In Situ* to Pipeline to Disposal Cell

Phase diagram representation

Volumes		Weights
V_a	AIR (zero for saturated sediments)	W_a = zero
V_w	FLUID	W_w
V_s	SOLIDS	W_s (oven-dried weight)
V_t	TOTALS	W_t

Example particle- water structure



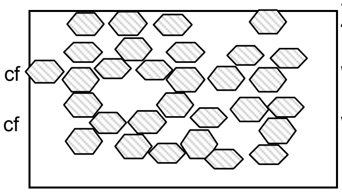
Percent solids by weight:	W_s / W_t
Water content:	W_w / W_s
Percent solids by volume:	V_s / V_t
Concentration:	W_s / V_t
Slurry density:	W_t / V_t
Volume solids (Vs)	$W_s / G_s \cdot \gamma_w$

Solids specific gravity 2.40
Fluid unit weight 63.3 pcf (1.015 Kg/m^3)

1. EXAMPLE IN-SITU SEDIMENTS
16 AUGUST 00

Wet weight 1400 Kg/m^3 (87.4 pcf)
C = 668 g/L or 41.7 pcf
27.8 % solids by volume
47.7 % solids by weight
w = 110 %

Vw = 0.722 cf
Vs = 0.278 cf



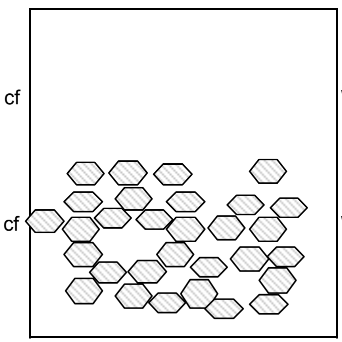
Ww = 45.7 lb
Ws =41.7 lb

V = 1.0 cf
W = 87.4 lb.

2. PIPELINE SLURRY
16 AUGUST AVERAGE

13.15 % solids by weight w = 660%
C = 144 g/L or 9 pcf 6 % solids by volume

Vw = 4.35 cf
Vs = 0.278 cf



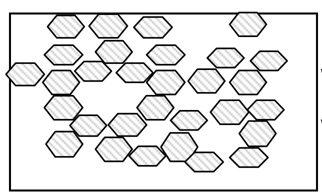
Ww = 275 lb
Ws = 41.7 lb

V = 4.63 cf
W = 317 lb

3. IN DISPOSAL SITE
(Based on Settling Column and
Self-weight Consolidation)

C = 500 g/L or 31.2 pcf
38.4 % solids by weight
20.8 % solids by volume
w = 161 %

Vw = 1.06 cf
Vs = 0.278 cf



Ww = 67.1 lb
Ws = 41.7 lb

V = 1.34 cf
W = 108.7 lb.

Table 3-1
Geotechnical Symbols and Definitions Used in the Evaluation of Solids Concentration

Symbol	Definition
W_s	Weight of oven-dried solid particles
W_f	Weight of pore fluid surrounding solid particles
W_w	Weight of pure water
V_s	Volume of compressed, oven-dried solid particles
V_f	Volume of pore fluid surrounding solid particles
W_t	Weight of solids and pore fluid
V_t	Volume of solids and pore fluids, which is total volume of sediment or slurry
V_w	Volume of pure water
P_{sw}	Percent solids by weight, which is defined as W_s / W_t times 100
w	Moisture content, which is defined as W_f / W_s. This is used in geotechnical engineering and can be greater than 100 percent.
C	Concentration or dry density, which is defined as W_s / V_t. This can be expressed as Kilograms per cubic meter (Kg / m3), gram per liter (g/L), or pounds per cubic foot (pcf).
d_t or γ_t	Wet unit weight, also called total unit weight or wet density, is defined as W_t / V_t. The symbol γ is often used for this ratio.
d_f or γ_f	Pore fluid density or fluid unit weight is defined as W_f/ V_f
d_w or γ_w	Water density or water unit weight is defined as the density of pure water (62.4 pcf or 1,000 Kg / m3).
G_s	Specific gravity of oven-dried solids. This is the unit weight of dry, compressed solids divided by the unit weight of pure water. This is analogous to the unit weight of solid rock.
G_m	Specific gravity of sediment or slurry mixture. This is the unit weight of a solid/water mixture divided by the unit weight of pure water.
G_f	Specific gravity of fluid, which is the unit weight of the fluid divided by the unit weight of pure water. The value of 1.026 is typically used for seawater (64.0 pcf / 62.4 pcf). For this project, the fluid is assumed to be a mixture of fresh and salt water and a fluid specific gravity of 1.015 was used in calculations.
P_{sv}	Percent solids by volume, which is defined as V_s / V_t times 100. This is the ratio of the volume of solids divided by the volume of slurry. The volume of solids can not be measured directly, but is calculated as W_s / (G_s d_w).

Dredging contractors often use the term "percent volume" to describe the ratio of *in situ* sediment volume to the volume of the slurry mixture in the pipeline. This is a useful ratio for dredging because it summarizes the ratio of how much volume must be pumped by hydraulic dredges for each *in situ* cubic yard of sediment removed. For example, if 5 cf of slurry is pumped to remove 1 cf of sediment, then the percent volume would be 20 percent (1/5 times 100).

The dredging contractor "percent volume" does not account for solids concentrations in either the *in situ* sediment or pipeline slurry. This is not the same as the percent solids by volume defined above, which is directly related to solids concentrations. Due to potential confusion with volume percentages, these terms are not used in this report in describing concentration relationships.

In situ Sediment Concentrations

Table 3-2 summarizes the concentration data for the sediment dredged from August 13 to August 18, 2000 during the PDFT. In this table the "Given Data" are values measured during the pre-dredge sampling. The "sediment specific gravity", G_m, is the measured slurry specific gravity on the dredge in Loop 3. In the BELLC data reports, this is shown as the wet unit weight of slurry in Kg/m^3, which in metric unit is simply 1,000 times the slurry specific gravity. The "specific gravity of solids" is based on the values measured in the pre-dredge core samples, as reported in Appendix B and F. The "fluid density" is the same as BELLC used in their calculations in Appendix F. All the ratios under "Calculated Ratios" are calculated from the given values.

The sediment had *in situ* specific gravity of mixtures of 1.26 to 1.41, which corresponds to concentrations of 425 to 668 g/L, wet unit weights of 78.6 to 88.0 pcf (1,260 to 1,410 Kg/m^3), solids by weight of 33.8 to 48.6 percent, and moisture contents of 196 to 110 percent. The organic content of the sediment varied between 4 and 12%. These values are typical for very soft, silt or clay marine sediments with natural organic material.

Pipeline Concentrations

Table 3-3 summarized the concentration data for the dredged material slurry pumped from the barge (as measured in loop 3 for each day from August 13 to August 18, 2000. In this table the "Given Data" are the slurry percent solids by weight, which is measured on the barge during dredging. The sediment solids specific gravity and pore fluid density are the same values measured in the pre-dredge sampling each day.

The average solids by weight ranged from 11.0 to 13.2 percent from August 16-18, which were the days that are closest to expected production. This corresponds to concentrations of 120 to 144 g/L and wet unit weights of 67.6 to 68.5 pcf (1,080 to 1,100 Kg/m^3).

The table also shows calculated ratios for pipeline solids contents ranging from 12 to 28 percent by weight. During full scale dredging, once all system configurations have been optimized and the operators comfortable with the debris management characteristics and range of *in situ* sediment densities to be encountered during dredging, the average concentration is expected to be higher than that experienced during the PDFT test. With production solids contents of 16 to 20 percent by weight, a reasonable assumption for the full scale dredging system, the concentrations would be 180 to 230 g/L and wet unit weights would be 70 to 72 pcf (1,120 to 1,150 Kg/m^3).

Table 3-2
Calculated *In Situ* Sediment Characteristics

	GIVEN DATA			CALCULATED RATIOS						
	Sediment Specific Gravity	Specific Gravity of solids	Fluid Density (pcf)	Wet density (pcf)	Fluid Density (Kg/L)	Solids by volume (percent)	Water Content (percent)	Solids by weight (percent)	Concentration or dry density (pcf)	Concentration or dry density (g/L)
	G_m	G_s	d_f	d_t	d_f	P_{sv}	w	P_{sw}	C	C
Insitu sediment										
13-Aug	1.270	2.40	63.3	79.2	1.014	18.4	187	34.9	27.6	442.7
14-Aug	1.280	2.40	63.3	79.9	1.014	19.2	178	35.9	28.7	460
15-Aug	1.380	2.40	63.3	86.1	1.014	26.4	118	45.9	39.5	633
16-Aug	1.400	2.40	63.3	87.4	1.014	27.8	110	47.7	41.7	668
17-Aug	1.410	2.40	63.3	88.0	1.014	28.5	106	48.6	42.8	685
18-Aug	1.260	2.40	63.3	78.6	1.014	17.7	196	33.8	26.5	425
C	1.10	2.40	63.3	68.6	1.014	6.2	642	13.5	9.2	148
A	1.15	2.40	63.3	71.8	1.014	9.8	390	20.4	14.7	235
L	1.20	2.40	63.3	74.9	1.014	13.4	273	26.8	20.1	321
C	1.25	2.40	63.3	78	1.014	17.0	206	32.6	25.5	408
U	1.30	2.40	63.3	81	1.014	20.6	163	38.1	30.9	495
L	1.35	2.40	63.3	84	1.014	24.2	132	43.1	36.3	581
A	1.40	2.40	63.3	87	1.014	27.8	110	47.7	41.7	668
T	1.45	2.40	63.3	90	1.014	31.4	92	52.0	47.1	754
E	1.50	2.40	63.3	94	1.014	35.0	78	56.1	52.5	841
D	1.55	2.40	63.3	97	1.014	38.7	67	59.9	57.9	928
	1.60	2.40	63.3	100	1.014	42.3	58	63.4	63.3	1014
	1.303	2.40	63.3	81	1.014	20.8	161	38.4	31.2	500

Table 3-3
Calculated Slurry Characteristics
(BELLC 3rd Loop)

	GIVEN DATA			CALCULATED RATIOS						
	Solids by weight (percent)	Specific Gravity of solids	Fluid Density (pcf)	Water Content (percent)	Solids by volume (percent)	Concentration or dry density (pcf)	Fluid Density (Kg/L)	Concentration (g/L)	Slurry Density or wet density (pcf)	Slurry Specific Gravity
	P_{sw}	G	g_f	w	P_{sv}	C	d_f	C	d_t	
BEAN 3rd loop (daily averages)										
13-Aug	8.83	2.40	63.3	1033	3.9	5.89	1.014	94	66.7	1.07
14-Aug	9.44	2.40	63.3	959	4.2	6.32	1.014	101	66.9	1.07
15-Aug	10.33	2.40	63.3	868	4.6	7.0	1.014	111	67.3	1.08
16-Aug	13.15	2.40	63.3	660	6.0	9.0	1.014	144	68.5	1.10
17-Aug	13.08	2.40	63.3	665	6.0	9.0	1.014	144	68.5	1.10
18-Aug	11.02	2.40	63.3	807	5.0	7.4	1.014	119	67.6	1.08
C	12.0	2.40	63.3	733	5.4	8.2	1.014	131	68.0	1.09
A	14.0	2.40	63.3	614	6.4	9.6	1.014	155	68.9	1.10
L	16.0	2.40	63.3	525	7.5	11.2	1.014	179	69.7	1.12
C	17.0	2.40	63.3	488	8.0	11.9	1.014	191	70.2	1.12
U	18.0	2.40	63.3	456	8.5	12.7	1.014	204	70.6	1.13
L	19.0	2.40	63.3	426	9.0	13.5	1.014	216	71.1	1.14
A	20.0	2.40	63.3	400	9.6	14.3	1.014	229	71.6	1.15
T	22.0	2.40	63.3	355	10.7	16.0	1.014	256	72.5	1.16
E	24.0	2.40	63.3	317	11.8	17.6	1.014	283	73.5	1.18
D	26.0	2.40	63.3	285	12.9	19.4	1.014	310	74.5	1.19
	28.0	2.40	63.3	257	14.1	21.1	1.014	339	75.5	1.21

Concentrations of *in situ* sediment and pipeline slurries are useful because the total volume of sediment or slurry is inversely proportional to concentration. In mathematical terms: $V_1C_1 = V_2C_2$ or $V_2/V_1 = C_1 / C_2$. For example, if the concentrations are 600 g/L *in situ* and 100 g/L in the pipeline, the pipeline volume will be 6 times the *in situ* volume (600/100). If the pipeline concentration is raised to 150, then the pipeline volume would only be 4 times the *in situ* volume (600/150).

The lower portion of Figure 3-13 shows schematic representations of the *in situ* sediments in the PDFT dredge area and average pipeline slurry using data from August 16 for illustration. The figure also shows a disposal site representation, which is discussed below. In this figure, one cf of *in situ* sediment is represented in each step. By conservation of mass, the dry weight of solids is constant throughout dredging and disposal (which is 41.7 pounds in the example shown). Since there is no air in saturated sediment, the difference in volumes and unit weights is due only to the addition or subtraction of water.

The *in situ* sediment dredged on August 16 had a concentration of 668 g/L and a wet unit weight of 87.4 pcf (1,400 Kg/m^3). This corresponds to 47.7 percent solids by weight and a moisture content of 110 percent.

In the pipeline slurry, the concentration was 144 g/L and had a wet weight of 317 pounds with a volume of 4.63 cf (68.5 pcf or 1,100 Kg/m^3). The dry weight of solids and the corresponding volume of dry solids is constant; therefore, the difference between *in situ* volume and pipeline volume is the amount of water added to make the slurry, which is 3.63 cf per cf of *in situ* sediment.

If the slurry concentration was increased from 13 percent to 20 percent by weight, the concentration would be increased from 144 g/L to 230 g/L. In this case, the volume in the pipeline would be 2.90(668 g/L / 230 g/L) times the *in situ* volume. The volume of water added would then be 1.90 cf per cf of *in situ* sediment.

Sediment Concentrations in Disposal Cell

Sediment concentrations in the disposal cell can be estimated using data from this dredge test and data from laboratory column settling, self-weight consolidation and column consolidation tests. All these tests were performed on a composite sample of fine-grained sediment from New Bedford. The sand portion of the sediment was removed prior to performing these laboratory tests.

Column consolidation tests were performed on sediment mixtures with concentrations of 42, 94, 178 and 515 g/L. At the completion of column settling, the sediment concentrations were 454, 391, 390 and 549 g/L for the four tests, respectively. The column settling test is designed to model the concentration in sediment at the top of the sediment to water interface in a settling basin.

Sediment in a disposal cell continues to consolidate after discharge due to self-weight consolidation and due to consolidation of fill placed over the sediment. The initial consolidation that occurs under the weight of sediment under water in the settling basin is modeled in the laboratory by the self-weight consolidation test. The test performed on sediment with an initial concentration of 178 g/L showed concentrations that ranged from 265 g/L at a depth of 3 in. to 514 g/L at a depth of 27 in.

The column consolidation test models consolidation at very low loads. The tests performed on sediment with initial concentrations of 42 and 94 g/L showed that under stresses of about 50 pounds per square foot (psf), the concentrations would be about 500 g/L. A stress of 50 psf corresponds to a depth of 3 ft. below the sediment water interface in a disposal cell.

Bulking Factor

The ratio of sediment volume in the disposal cell (below the sediment/water interface) to the *in situ* volume is the "bulking factor". The bulking factor depends on many variables including initial sediment concentration, method of dredging and disposal, rate of dredging, type of dewatering in the disposal cell, depth of disposal cell, and weight of fill over the sediment in the disposal cell. The data can be used to make estimates of bulking for the sediment dredged during the PDFT.

The sediment dredged on August 16 had an *in situ* concentration of 668 g/L. In those areas where the dredged sediment contains little sand, the bulking can be estimated using a concentration of 500 g/L in the disposal cell. Figure 3-13 shows the estimated conditions in sediment in the disposal cell with a concentration of 500 g/L. The volume would be 1.34 cf, which gives a bulking factor of 1.34.

The *in situ* sediment concentration in the dredge test area ranged from 425 to 668 g/L.

The bulking factor decreases when the percentage of sand in the sediment increases. The bulking factor for loose sand and gravel is close to 1.0 because the sand settles quickly and the settling that occurs in a disposal cell is similar to natural settlement that occurs in the Harbor. Extra space in the disposal cells has to be reserved to allow for settlement of the sediment from the slurry discharged in the cells.

Disposal

The dredged material slurry was discharged adjacent to the eastern sheetpile wall, halfway into Cell No.1. To allow visual inspection of the slurry discharge, the end of the discharge pipeline was held 2-3 ft. above the water surface with the aid of a backhoe. After 2-3 days, the coarse materials (mainly shells) present in the slurry had stacked and broke the water surface. To mitigate odors in the vicinity of the CDF by preventing further stacking of the dredged material above the water surface, the pipeline was shortened, by cutting off approximately 20 ft., so that the discharge could be re-directed to another open area in the CDF. An oil absorption boom was installed around the discharge point to minimize the extent of the oil sheen in the CDF.

The 8-inch HDPE pipeline used as the discharge pipeline came off the 3rd SG Loop on the dredge and was lashed to the 16-inch HDPE line, along with the 8-inch recirculation water pipeline, for flotation. When the discharge pipeline was being used it had a tendency to sink up to 2-3 ft., due to wear in the connection with the flotation line. Navigation lights that had been attached to the top of the flotation pipeline did not generally stay attached due to poor connections, wind and wave conditions, and perhaps vandalism.

Solids Concentration of Dredge Slurry

The solids concentration during hydraulic transport of the slurry is governed by the following elements:

- Minimum required velocity in the discharge line.
- Maximum density at which pipeline resistance can be overcome by the maximum pressure generated by the slurry pump.
- Quantity of material discharged in the hopper by the excavator.

Maximum instantaneous volume concentrations between 65 and 85% were achieved corresponding with densities up to 1,270 Kg/m^3 related to *in situ* (wet) densities between 1,260 and 1,410 Kg/m^3. Averages over longer periods of time showed volume concentrations between 25% and 55%.

Average sustained solids concentration values recorded by the SPU system over sustained dredging periods ranged from 13.3% to 16.3% solids by weight. These concentrations were achieved in dredge areas having *in situ* sediments with average solids concentrations of 32% to 43% solids by weight. This corresponds to volume concentrations in the order of 40% to 50%, by volume. The solids concentration values attained by the BELLC dredge were affected by debris. Higher solids concentrations would be attainable with inclusion of a more sophisticated debris separation system on the full-scale project.

The use of the SPU on the cleanup of the Upper and Lower Harbors, could reduce the volume of water transported and treated by an estimated 50% to 70% below that required for a hydraulic cutterhead system. A specific range of slurry density could be prescribed and provided by the SPU, that would best accommodate the decanting time, re-circulation water pressure, and movement of dredge material disposal operations within the CDF's.

3.1.4 Recirculation System

A significant aspect of the PDFT was the successful demonstration of the dredge effluent water recirculation system. The recirculation system essentially created a closed loop system, whereby the only water added to the dredge process was that entrained in the dredge bucket. This water addition amounts to approximately 40% of the *in situ* volume. The water was recycled back to the dredge for use as make up water for the SPU system and as jet water for debris dislodgment in the suction line. As controlled by the SPU, excess recirculation water was directed back to the hopper, from the discharge line, and recycled in the hydraulic slurry transport system. No water was used from the sea chest for makeup water for hydraulic slurry transport.

The recirculation system operated without any significant problems. Only one delay was caused by the recirculation system, when the return water pump lost its prime.

The entire dredge test was carried out using recirculation water from the CDF. No outboard water was used for the make-up pump.

3.1.5 Mass Balance

The total volume of water and dredged material was measured to derive the mass balance for the PDFT. Water levels in Cell 1 and Cell 2 of the Sawyer Street CDF were measured at the start and stop of dredging each day of test dredging, and additions or losses from the system were accounted for.

No dredged material or large volume of water had been placed in Cell 1, since its resurfacing and lining, until the PDFT. No survey was performed in Cell 1 to determine the volume of the dredged material in Cell 1 due to the PDFT.

- The total volume of dredged material slurry added to the Sawyer Street CDF was measured to be 4,204 cy.
- A volume of water added to Cell 1 to suppress air emissions/odor was estimated to be 1,338 cy.
- The volume of rainwater added to the system during the period of performance was measured to be 351 cy by the site meteorological station.
- The estimated volume lost due to evaporation was 257 cy.

- The volume of water lost on the dredge due to overflow of the recirculation water in the hopper was estimated to be 267 cy.
- To account for the likely consolidation of the loose liner and the underlying sand surface, a 1-inch consolidation was applied across Cell 1, for an estimated volume of 270 cy.
- The volume of material removed from the dredge area was calculated to be 2,308 cy based on comparison of the pre- and post-dredge hydrographic surveys of the dredge area.

Based on the measurements and calculations listed above (and shown in Table 3-4), the net volume of water added to the CDF is 1,001 cy.

The calculated volume dredged and pumped shown in Table 3-4 is based on pre- and post-dredge surveys at the dredge site and pre- and post- dredge water level measurements in the disposal pond. For comparison, the estimated *in situ* dredge volume based on BELLC calculations is 2,111 cy (193+340+325+424+537+292 cy). In this case, the ratio of survey volume to estimated is 1.09 (2,308/2,111).

Table 3-4
Mass Balance Calculations of Percent Solids by Volume

	Description	Start	Stop	Volume (cy)
A	Total Volume of Slurry and Water Added	8/10/00 14:10	8/20/00 12:20	4204
B	Volume of Water Used to suppress odor	8/19/00 09:00	8/19/00 12:00	1338
C	Volume of Rain Water	8/10/00 14:10	8/20/00 12:20	351
D	Volume of Water Evaporation	8/10/00 14:10	8/20/00 12:20	257
E	Volume of Losses on dredge	8/10/00 14:10	8/18/00 17:45	267
F	Volume Loss due to Consolidation	8/10/00 14:10	8/20/00 12:20	270
G	Dredged Material Volume (from Post-Survey)	8/10/00 14:10	8/18/00 17:45	2308
H	Net Volume of Water Added by Dredging (=A-B-C+D+E+F-G)	8/10/00 14:10	8/20/00 12:20	1001
	Ratio of *in situ* volume dredged (G) to volume slurry pumped (G+H)			**70%**

The total volume of slurry discharged from the dredge is 9,686 cy (891+1522+1818+1924+2509+1022 cy) based on flow measurement by BELLC. Based on the *in situ* volume dredged measured by survey (2,308 cy) divided by the volume slurry pumped (9,686 cy), the ratio of *in situ* volume to slurry pumped is 23.8%.

A significant aspect of the PDFT was the successful demonstration of the dredge effluent water recirculation system. The entire dredge test was carried out using recirculation water from the CDF. No outboard water was used for the make-up pump. The recirculation system essentially created a closed loop system, whereby the only water added to the dredge process was that entrained in the dredge bucket. This water addition amounts to about 1,001 cy (item H in Table 3-4), which is 43% of the *in situ* volume. The water was recycled back to the dredge for use as make up water for the SPU system and as jet water for debris dislodgment in the suction line. As controlled by the SPU, excess recirculation water was directed back to the hopper, from the discharge line, to decrease water content and increase the solids concentration of the dredge slurry. No water was used from the sea chest for makeup water for hydraulic slurry transport. For comparison, without the recirculation system, the volume of water added would be 7,378 cy (9,686-2,308), which is 320% of the *in situ* volume.

4.0 ENVIRONMENTAL MONITORING

4.1 Overview

The PDFT was undertaken to evaluate performance of the hybrid environmental dredge technology being considered for remediating the New Bedford Harbor Superfund Site. The environmental monitoring objectives of the PDFT included: 1) evaluating actual dredge performance relative to removal of contaminated sediments; 2) evaluating the dredge's ability to minimize environmental impact to water quality by measuring the extent of contaminated sediment resuspension and transport; and 3) evaluating impacts to local air quality. These performance aspects are evaluated in the following sections.

4.2 PCB Removal Efficiency

The evaluation of the dredge performance relative to removal of contaminated sediments included two components: 1) The first (primary) goal was to evaluate the dredge's ability to remove contaminated sediments to a given depth horizon relative to the dredging plan (Foster Wheeler Environmental Corporation – FWENC, 2000a). Results of this analysis are reported within Section 3 of the main report; and 2) A secondary objective was to determine how effectively the dredging technology could remove contaminated New Bedford Harbor sediments within the test area by comparing pre and post dredge PCB concentrations. This information was used to determine overall PCB mass removal efficiency and to evaluate the effectiveness of this technology with regard to site-specific cleanup levels under the conditions of the PDFT.

ENSR conducted the PCB contaminant characterization for the PDFT dredge technology evaluation. Details of this investigation are presented in Appendix J. The appendix includes comparison of pre- and post-dredge PCB concentrations as part of the overall efficiency evaluation. The work represents a joint effort by the EPA (New England Region and Atlantic Ecology Division), the USACE, and ENSR (under contract DACW 33-96-D-004 to the USACE).

Pre-dredge sediment core samples were collected at each of 40 stations which include 30 stations located in the original 100-foot x 400-foot dredge footprint of the test area and 10 additional stations in the provisional test area located immediately to the west (Figure J-2). Post-dredge cores were collected at stations where dredging was completed, and sampling methodology was similar to that of the pre-dredge effort. Post-dredge grab samples were collected adjacent to core locations and at other locations in the test area to assess surficial sediment conditions. The sediments collected for the dredge efficiency testing were analyzed for the 18 congeners selected by National Oceanographic and Atmospheric Administration (NOAA) for the National Status and Trends program and by the EPA EMAP program (hereafter referred to as the NOAA 18). Estimates of total PCBs were calculated based on a mathematical relationship among these parameters in New Bedford Harbor sediments determined by Foster Wheeler Environmental Corporation (FWENC, 2001b). This allows data comparisons to be made with historical Aroclor data and the more generally applicable homologue information. The regression formula used to calculate total PCB homologues from the NOAA 18 is:

Total PCBs = (2.5 x NOAA 18)

It should be emphasized that this is a site-specific relationship developed for New Bedford Harbor sediments only, and should not be applied at other sites.

The results of the PCB analyses for pre- and post-dredge sediment core and grab samples are presented in Appendix J, Tables J-3, J-4, and J-5. Figures 4-1 and 4-2, below, provide summary information on sediment type and PCB concentrations in the test area.

A review of the pre-dredge core logs in Figure 4-1 reveals that most of the pre-design area was overlain with a layer of black silty material. The thickness of this layer generally increased from east to west, ranging from several inches in Cut 14 to over 4 ft. in Cut E. This material appeared to have a high water content and often had a distinct hydrogen sulfide (H_2S) and/or petroleum odor. Sand was noted beneath the thin layer of silt material in the extreme eastern portion of the area. Over the remainder of the pre-design area, the black surficial deposit was underlain by a light gray, clay-like material.

For the cores that were analyzed, the PCB concentrations (ppm as total homologues) have been overlaid on the core logs in Figure 4-1. Each reported value represents the concentration in the 1-foot (0.3m) section of core that was composited for analysis. A review of Figure 4-1 reveals that elevated PCB concentrations are generally restricted to the silty surficial deposit. PCB concentrations ranged from several hundred to several thousand ppm for 1-foot (0.3m) composite core sections that consisted entirely of the silty material. The 1-foot (0.3m) composite core sections that were entirely situated in the underlying clay or sand deposit had no or very low (<10 ppm) detectable PCB concentrations.

Post-dredge core logs and PCB concentrations are presented in Figure 4-2. For the area that was dredged, the sample logs reveal a uniform layer of light gray, clay-like material generally overlain by a thin veneer of black, silty material. As described in Section 3.1 of the main report, dredging was performed only in cuts 1-8 and the southern portion of cut A (see Figure 3-1). In the physical description presented in Figure 4-2, the logs for locations 10 and 22 in cut 9, location 23 in cut 11, and location 12 in cut 13 represent areas that were not dredged. Post-dredge cores were collected at these locations to assess if sediment conditions changed adjacent to the dredged area.

For the cores and grabs that were analyzed, the PCB concentrations (ppm as total homologues) have been overlaid on the core logs in Figure 4-2. For the grabs, the PCB concentrations represent a composite of the 0-2 cm (0-0.8 inch) sediment depth. These concentrations are reported in the box above each core. For the cores, the PCB concentrations represent a composite of the 0-1 foot (0-0.3m) sediment depth. These concentrations are reported within each core.

PCB concentrations for the grabs (generally representing the black silty material) ranged from 0.47 ppm (location 2) to 470 ppm (location 31) and were generally above 100 ppm. Concentrations in the upper one foot (0.3m) composite from the cores ranged from 0.67 ppm (location 9) to 130 ppm (location 21) and were generally above 7 ppm. PCB concentrations were significantly higher in the grabs than in the upper 1-foot (0.3m) core composites at 16 of the 18 locations where both grabs and cores were analyzed.

<u>PCB Removal Efficiency of BELLC Test Dredge</u>

The Pre-Design Field Test was designed to, among other goals, determine the ability of the proposed dredge system to remove contaminated sediment without causing adverse ecological or human health effects. Efficiency was determined based on the ability to remove PCB-contaminated sediment down to the 10 ppm depth horizon. Based on pre-dredge sediment cores, a dredging plan was established to accomplish this. Two measurement endpoints were identified to evaluate this technology. The first was to compare the volume of sediment actually removed to the estimated volume to be removed based on the original dredge plan. This was accomplished using bathymetric data before and after the dredging to determine how effectively the dredge performed (Section 3.0). Comparison of the target dredge volume with the actual volume dredged yielded an overdredging value of only 16%, with vertical accuracy of +/- 4 inches relative to achieving the intended horizon.

A second endpoint designed to evaluate removal efficiency included determining the sediment PCB concentrations before and after dredging to calculate overall PCB removal efficiency of the dredge. The dredge was very efficient in this regard. The results indicate that approximately 97% of the PCB mass was removed within the dredging boundaries. The average PCB concentration in the upper one foot of sediments was reduced from 857 ppm to 29 ppm over the dredged test area. This met the clean up criteria of 50 ppm for the Lower Harbor and approached the criteria of 10 ppm for the Upper Harbor. It should be understood that the PDFT goal was **not** to leave a final sediment concentration of 10 ppm as this was a field test, **not** a remedial operation.

During the design phase of this project, it was determined that most sediments within the dredge test area had a high water and silt/clay content. This fact introduced the possibility that some contaminated sediment within or immediately adjacent to the dredge area could be mobilized during the dredging process and potentially re-contaminate the dredged area. Mechanisms that could mobilize the sediments include bucket impact on the bottom, loss through the water column (appears minimal for the hydraulic excavator), anchor wire/spud repositioning, and material sloughing down slope along the sides of a dredged cut. Furthermore, other factors such as tidal currents and meteorological events (e.g., wind) could produce the same effect due to re-suspended contaminated sediments migrating from other areas of the harbor. The sediment characterization program included the collection of surface grabs in addition to cores in an effort to quantify the effects of sediment mobilization.

Based on the visual observations of the upper surface of post-dredge cores and grab samples and the results of laboratory analyses, some recontamination did occur within the test area. Calculations presented in Appendix J (Section J.5) demonstrate that only a very thin layer of re-deposited, contaminated PCB sediment would be required to increase the concentration within a composited upper one foot (0.3 m) sediment core to greater than 10 ppm. For example, if the sediment adjacent to a clean dredge area has a PCB concentration of 1,000 ppm (as was the case in much of the test area), it would require only a 0.24-inch (0.61cm) layer of newly deposited (post-dredging) contaminated sediment to elevate the average concentration of the upper one foot of clean sediment above 10 ppm.

This thickness of contaminated silty material (only a thin veneer) is consistent with field observations made at the time of grab sample collection. The grab sampler penetrated approximately 6 inches (15 cm) into the sediment. Once retrieved, the top of the sampler was opened, and a portion of the upper 0.8 inches (2 cm) of sediment was removed for analysis. This allowed for visual inspection of the upper sediment profile within the sampler. Based on this information, it appears that the observed average post-dredge PCB concentration (29 ppm upper one foot composite) can be attributed to deposition of mobilized sediments (either from the original dredged area or from adjacent areas by sloughing, tidal action, etc.), rather than inefficient or inaccurate dredging.

In summary, both the sediment removal data and PCB data indicate that this dredging technology is very efficient at contaminated sediment removal. The results indicate that 97% of the PCB mass was removed over the test area, and the remaining sediment concentrations approached the site specific clean up criteria. The PCB mass remaining after dredging appeared to reside entirely in a thin surface veneer and was attributed to recontamination of the dredged area rather than incomplete removal. Adjustments to dredging and operational controls will reduce the influence of many potential recontamination mechanisms. Therefore, during full-scale dredging, a corresponding reduction in surficial sediment recontamination would be expected.

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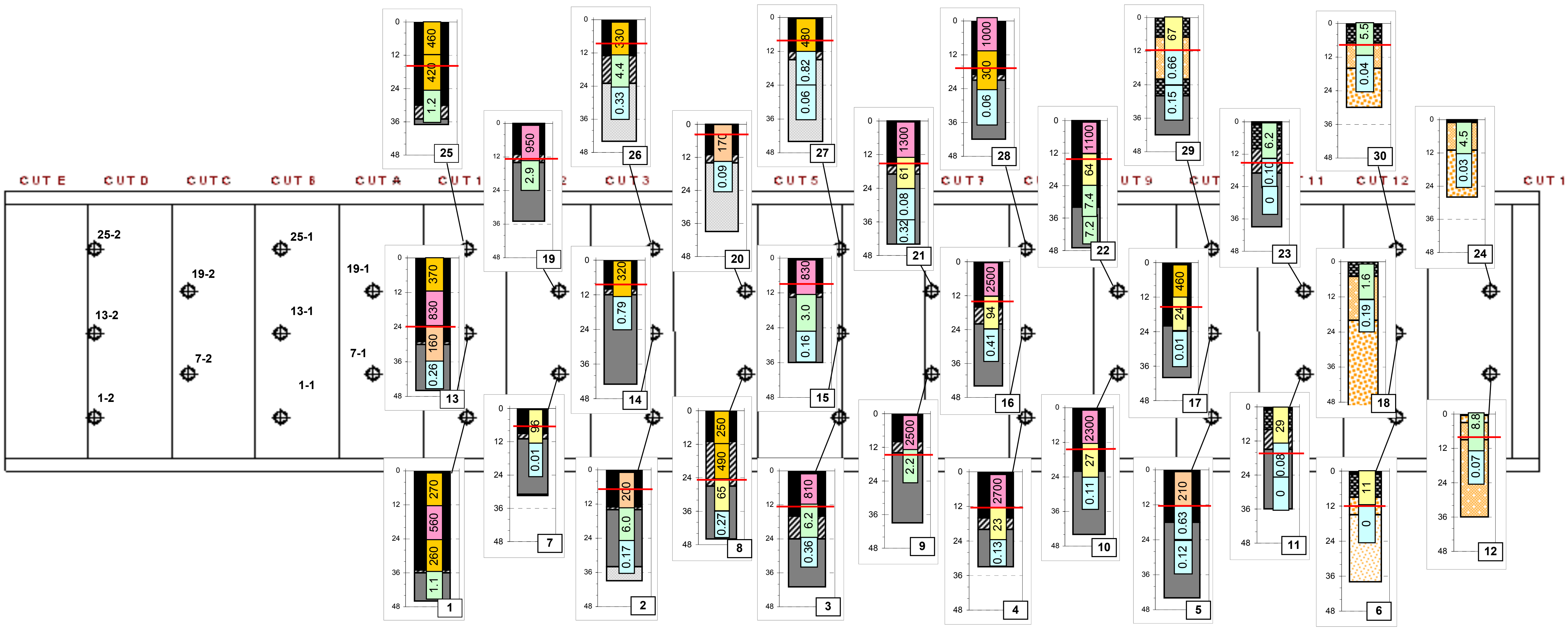


Visual Classification of Sediment Type

- Black-Very Fine (most with obvious H_2S and/or petroleum odor).
- Dark Grey-Fine
- Transition Layer (may be an artifact of coring)
- Grey Fines
- Light Grey Fines
- Silty Sand
- Coarse Sand
- Fine Sand
- Color change noted by lab after removing outer layer.

Notes

Depths are in inches from the sediment surface.
All PCB data have been surrogate-corrected.
Background stratigraphy is based on field observations.

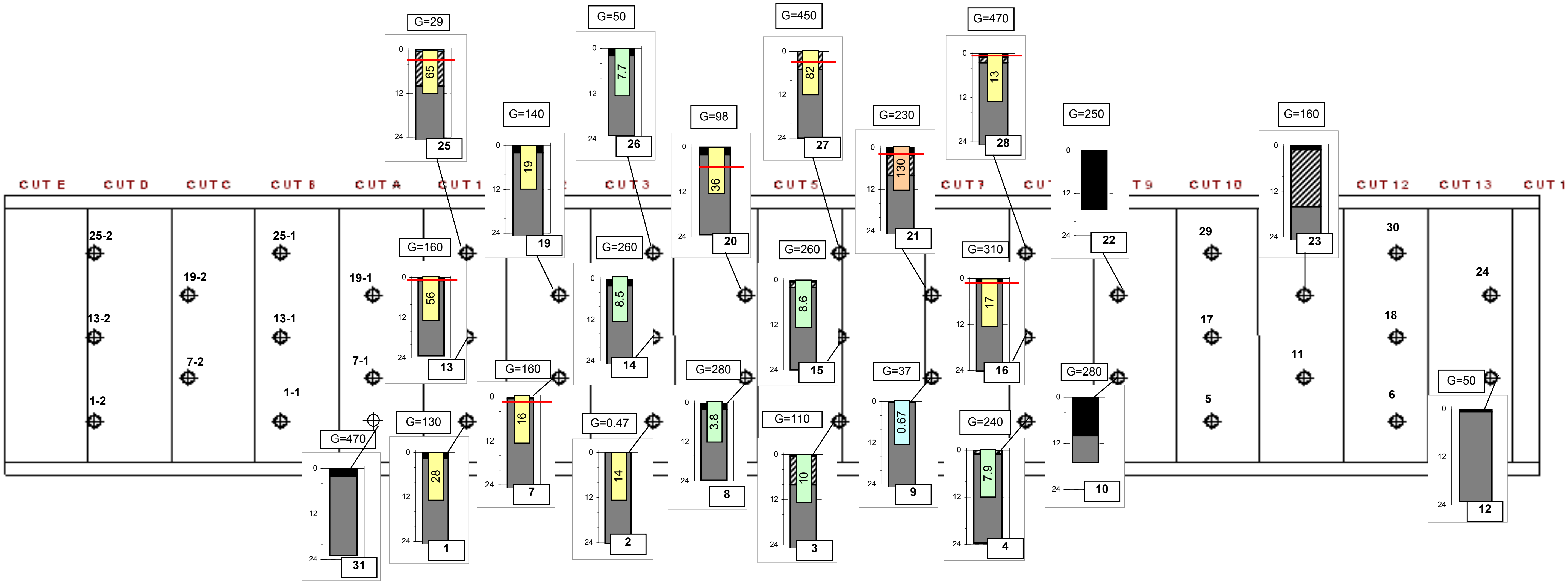
Total PCB (ppm as total homologues[1])

0	< 1 ppm
7	1-10 ppm
46	11-100 ppm
150	101-250 ppm
300	251-500 ppm
1062	> 500 ppm

[1] Calculated using Foster Wheeler's (February 2001) regression equation.
Total PCBs as homologues = NOAA 18 sum (ppm) * 2.5

Figure-4-1
Pre-Dredge Core Logs+PCB
06-06-01

FigJ4-CoreLogPlots_June2000_wPCBSurgCor



Visual Classification of Sediment Type

- Black-Very Fine (most with obvious H_2S and/or petroleum odor).
- Dark Grey-Fine
- Transition Layer (may be an artifact of coring)
- Grey Fines
- Light Grey Fines
- Silty Sand
- Coarse Sand
- Fine Sand
- Color Change noted by lab after removing outer layer, for top 12" only.

Notes

Depths are in inches from the sediment surface.
All PCB data have been surrogate-corrected.
"G" = Grab samples were collected from a depth of 0-2cm.
All PCB concentrations are expressed in ppm as total homologues.[1]
Cores 10, 12, 22, 23 were collected from an undredged area.
Background stratigraphy is based on field observations.

Total PCB (ppm as total homologues[1])

0	< 1 ppm
7	1-10 ppm
46	11-100 ppm
150	101-250 ppm
300	251-500 ppm
1062	> 500 ppm

[1] Calculated using Foster Wheeler's (February 2001) regression equation.
Equation used:
Total PCBs as homologues = NOAA 18 sum (ppm) * 2.5

Figure 4-2
Post-Dredge Core Logs+ PCB (Cores and Grabs)
06-06-01

4.3 Water Quality Monitoring

The test dredge's ability to minimize environmental impact to water quality (by limiting the extent of contaminated sediment resuspension and transport) was evaluated by ENSR. A detailed summary of the water quality monitoring program is presented in Appendix K. The water quality monitoring program conducted for the PDFT represents a joint effort by the EPA, the USACE, and ENSR (under contract DACW 33-96-D-004 to the USACE) and included the following components:

- Predictive modeling to aid in design of the water quality monitoring field program and to assess the utility of modeling for the full-scale remediation effort;
- Field monitoring to assess sediment resuspension during the dredging operation, to collect water samples for laboratory analysis, and to ground-truth the predictive modeling;
- Laboratory analysis of water samples (total suspended solids (TSS), PCBs) to assess water quality impacts; and
- Correlation assessment between the field and laboratory data.

The predictive modeling included development of a numerical hydrodynamic and sediment transport model based on previous work at New Bedford Harbor (USACE, 1988 and 2000). The modeling was used to predict the expected suspended sediment concentration resulting from dredging activities under a variety of transport assumptions. These predictions were used to help design the field monitoring program.

Field monitoring was performed in parallel with the dredging activities in August 2000. Objectives of the monitoring included real-time location and mapping of any turbidity plume associated with the dredging as well as collection of water samples at designated stations downstream of the dredge for laboratory analysis. The monitoring program was structured to document water column conditions in the Upper Harbor over the course of ebb and flood tidal events during dredging operations. Water samples were analyzed for TSS and dissolved and particulate PCBs. An assessment of the correlation of the field turbidity and laboratory TSS data as well as the laboratory TSS and PCB data was also performed.

Water column turbidity measurements were performed using an optical backscatter sensor (OBS). Turbidity monitoring was initiated prior to the start of dredging operations for each day of monitoring in order to characterize baseline turbidity conditions within the Upper Harbor. After dredging began, the water quality conditions were closely monitored to assess the development and the aerial extent of any elevations of turbidity from baseline conditions. The results of the model predictions presented in Section K.2 were used to initially set target distances for the transects (locations where an elevation of turbidity was expected). This initial turbidity tracking was conducted for one hour after the start of active production dredging, after which the position of down-current stations was set for collecting TSS and PCB samples. Turbidity data continued to be collected in the Upper Harbor during each monitoring event, and selective east-west or north-south transects were performed to document changing water column conditions.

Sampling for TSS and PCB analyses was performed over four discrete tidal events (ebb/flood on August 16 and ebb/flood on August 17) while dredging operations were ongoing. For the monitoring performed on August 16, stations were set at 50 ft., 100 ft., and 500 ft. down current of the dredging as well as a reference station 1,000 ft. up current. For the monitoring performed on August 17, an additional down-current station was added, and stations were set at 50 ft., 300 ft., 700 ft., and 1,000 ft. down current of the dredging based on a review of the previous day's data.

Water Quality Impacts Related to Dredging Operation

The water quality monitoring performed during dredging on August 16-18 provided data over a range of operational and environmental conditions. Upon examination of the data, the following conclusions can be made:

- The actual dredging process (removal of sediments with the hydraulic excavator) appeared to have a limited impact on the water column;
- Activities performed in support of the dredging (operation of support vessels) appeared to have a much greater impact on water quality than the dredging; and
- Normal fluctuations in water quality occur in the Upper Harbor related to changing environmental conditions that appear similar or greater in scale than the overall impacts related to the dredging operation.

The monitoring performed during the ebb tide on August 16 provides the best representation of impacts associated specifically with dredging. Dredging was performed with limited shutdown during this monitoring period, and there was limited support vessel activity. Although rainfall occurred on the morning of the 16th, the effect of the runoff was assumed similar for all the composite samples (both up and down current). Field measured turbidity showed some spikes in the vicinity of the dredge but generally returned to background levels within 500 ft. down current of the dredge. Total particulate PCB concentrations were elevated in the vicinity of the dredge, but returned to background levels within 500 ft. down current of the dredge. During the other monitoring events, some of the turbidity transects revealed little or no detectable elevation of turbidity down current of the dredge. Larger increases in turbidity were generally traceable to dredge support activities or environmental conditions as discussed below.

The limited water column impacts associated specifically with the dredging are attributed to both operational and environmental factors. The design of the bucket (tight closing with limited leakage), the configuration of the dredge (with a "moon-pool" work area enclosed behind a 36-in. silt curtain), and the controlled manner in which the operation was executed all contributed to minimizing the release of material to the water column. The shallowness of the area (maximum depth of the dredged area was less than 10 ft. at high tide) and the limited currents (maximum currents generally less than 0.5 ft./s) limited transport away from the dredging area.

Difficulties associated with handling and transferring sediments containing debris and a large component of embedded shells did cause regular suspensions of dredging operations. However, the periods of continuous dredging were sufficient enough to allow setup of "steady state" conditions in the near field area (within 200 ft. of the dredge) included in the monitoring. More continuous dredging over a full or multiple tidal cycles would not be expected to generate a turbidity plume of greater extent in the nearfield area down current of the dredge than that observed during the field test.

Water Quality Impacts Related to Dredging Support Activities

The aerial photographs presented in Figure K-26 provide a good example of the potential water quality impacts of support activities relative to the dredging operation. The photos were taken approximately midway through the ebb tide on August 17. At the time the upper photo was taken, the dredge was not in operation, and the tug *Miami II* was moving a support barge from the dredge to the shore. Because of the pipeline/dredge configuration, the tug had to transit in shallow water to the east of the dredge (estimated at 4 to 5 ft. in depth at this tidal stage) creating a large turbidity plume in the process.

The water-quality monitoring vessel can be seen taking measurements within the plume in the same photo. A water sample collected within 50 ft. of the tug after its passage had a suspended solids concentration of 300 mg/L and particulate and dissolved PCB concentrations of 26 and 2.7 micrograms per liter (µg/L), respectively (reported as the sum of the 18 NOAA congeners). Background suspended solids and total PCB concentrations at the up current reference station on August 17 were 5 mg/L and 0.75 µg/L, respectively. Although the dredge was not in operation when the upper photo was taken, monitoring performed earlier during nearly continuous dredging operations recorded a plume of much less extent than that associated with the tug.

In the lower photo taken approximately 30 minutes later, the dredge had resumed operations, and the tug was pushing ahead to hold the barge at the shore support area. A large turbidity plume is again visible behind the tug, being carried to the south on the ebb tide.

Water Quality Fluctuations Related to Environmental Factors

The monitoring performed in support of this field test reinforced the importance of understanding the normal fluctuations in water quality that occur independent of the operation being monitored. The PCB concentrations in background samples that were collected in the Upper Harbor on August 7 during the ebb tide prior to the start of the dredging operation were higher by a factor of three for the station 1,000 ft. north of the pre-design area than for a station 1,000 ft. south of the pre-design area (both particulate and dissolved PCB).

The flood-tide monitoring performed on August 16 provides a good example of normal fluctuations of turbidity within the Upper Harbor. Turbidity values at the background station increased from approximately 10 Nephelometric Turbidity Units (NTU) at the start of monitoring to nearly 200 NTU an hour later (higher values than those recorded downstream of the dredge, see Figure K-12). This increase in turbidity was attributed to storm-water discharge to the harbor following the rainfall earlier in the day. By the end of the monitoring period, the entire monitoring area displayed an elevated turbidity of approximately 30-60 NTU (Figure K-13). The elevated turbidity values were not, however, accompanied by increased PCB concentrations at the background station.

4.4 Air Sampling and Analysis

Different types of air samples were collected to achieve various objectives during the PDFT. These included the following:

- Flux chamber sampling provided a measure of emissions as an indication of the relative contributions from the various operations to the ambient air concentrations. These will also be used to support the emissions and dispersion modeling calculations performed as part of developing ambient air action levels for upcoming construction work. In addition to flux chamber samples collected in the field, sediment from the bench scale dewatering studies was tested at the USACE Waterways Experiment Station (WES) for emissions measurements. Test results were reported to USACE.
- Ambient air sampling and analysis was performed from locations around the CDF and harbor to document concentrations during operations.

Sampling was conducted in accordance with the Foster Wheeler TO #17 *Sampling and Analysis Plan* (SAP), Revision #6, dated August 2000 (FWENC, 2000c). The data from these tests are summarized and discussed in the following sections.

4.4.1 Flux Chamber Sampling and Analysis

Flux chamber sampling and analysis was performed by URS Corporation and is detailed in their report included in Appendix L and summarized in Table 4-1. These data are summarized here as a useful indication of relative emission fluxes from the dredge test and to provide engineering design information for future dredging and CDF construction/filling activities. In addition, these data will be used to support the emissions and dispersion modeling efforts being conducted as part of developing the ambient air action levels for future construction activities. Note that this is a limited data set, collected during a single one-week test period. As such, these results do not correlate directly to ambient air concentrations or represent all of the conditions affecting emissions and subsequently ambient air concentrations. These data do provide an indication of relative emissions sources and are useful in evaluating impacts to ambient air quality. The results are discussed in that context below.

Flux chamber samples were collected by isolating a given surface area (0.13 m^2) with the chamber and drawing clean sweep gas (0.005 m^3/min) into the chamber, across the surface and drawing the resulting emission gas through XAD resin for subsequent laboratory analysis for PCBs. URS subcontracted the laboratory analysis of the XAD resin air samples to Alta Analytical Laboratory. Samples were analyzed using high resolution gas chromatography (GC) and high resolution mass spectrometry (MS) operating in selected ion monitoring (SIM) mode for NOAA and World Health Organization (WHO) congeners and total PCB homologue groups.

Samples of source media (sediment, water, and mixtures) were collected by URS and provided to Foster Wheeler for compositing and subsequent analysis. Samples were analyzed by Severn Trent – VT Laboratory for NOAA PCB congeners analysis using GC with an electron capture detector (ECD). NOAA congener results were corrected to the total PCB equivalent using the regression equation with a slope of 2.5 and a zero y-intercept developed by Foster Wheeler and reported in the *Draft Final Comparison of PCB NOAA Congeners with Total Homologue Group Concentrations* Technical Memorandum, dated May 2001 (FWENC, 2001b). Laboratory results are included in Appendix L. Total PCB results are summarized in Table 4-1.

Table 4-1
Summary of Source Material and Flux Chamber Data

Test ID	Description of Flux Chamber Test and Source Material		PCB Concentration of Source Material **	Measured PCB Emission Flux (ng/m^2-min)	Average PCB Flux (ng/m^2-min)
CDF Emission Sources					
A[1]	Fresh sediment discharge from the dredge pipe to the CDF. Sediment was collected from the CDF with a 5-gallon bucket and transferred to wash basin.		14 ppm	901 2,440 4,090	2,477
B[1]	Two inches of harbor water added to the sediment in the wash basin from test A.		18 ppm	666 2,930 3,990	2,529
C[1]	Aqueous / sediment mix collected from inside boom in CDF over water cover with a visible sheen, ~50 ft from discharge pipe.		1,400 ppm	3,320 2,800	3,060
			no sample	1,320	1,320
D[1]	Aqueous / sediment mix collected from the CDF water cover near the sheen (C) where no sheen was present ~ 15 and 25 ft from C.		38 ppm	1,280 1,430	1,355
E[1]	Aqueous / sediment mix from surface of CDF after application of surfactant:	Dawn	60 ppm	4,700	4,060
		Biosolve	45 ppm	3,420	
		Simple Green	no sample	925	925
Dredge Emission Sources					
F[2]	Aqueous sample from the moon pool at the dredge.		5 ppb	86 303	195
			24 ppb	896 934	915
G[2]	Aqueous surface sample of the water near the dredge, outside of the moon pool:	Just outside silt fence 40 ft from silt fence 47 ft from silt fence	4 ppb	127 282 230	213
				ng/m^3	**ng/m^3**
H	Headspace concentrations at the grizzly – (ng/m^3)		NA - headspace measurement	2,070 4,270 6,100	4,147
Background Emission Sources				**(ng/m^2-min)**	**(ng/m^2-min)**
I[3]	Sediment from mudflats near previous locations (see Sec. 4.4.1.3):	@ loc. S-657 >10K ppm	11,000 ppm	600	600
		@ loc. S-602 ~9,500 ppm	100 ppm	132	132
		@ loc. S-650~36 ppm @ loc. S-650 (2nd ft) 6,600 ppm	210 ppm	63	63

** Total PCBs were calculated using the regression equation: total NOAA congeners multiplied by a slope of 2.5 and a y-intercept of zero based on the Foster Wheeler Draft Final Technical Memorandum, *Comparison of PCB NOAA Congeners with Total Homologue Group Concentrations*, May 2001.

1 Source material samples were an aqueous/sediment slurry, easily mixed by shaking. Samples were shaken, transferred with a pipette, weighed, extracted and reported on a wet weight basis (mg/kg).

2 Source material samples were aqueous samples of surface water from the harbor (µg/L).

3 Source material samples were sediment samples from approximately the same locations as sampled during the harbor delineation program, reported on a dry weight basis. Flux chamber source samples were surface grabs. Samples from the previous program (S-657, S-602, and S-650) were composites over the upper one-foot interval, except for S-650, where results from both the upper one-foot composite and second foot composite are provided.

Flux chamber sample total PCB results and those from source media samples (collected by Foster Wheeler) are summarized in Table 4-1. Flux chamber samples were collected from nine different potential sources of PCB emissions denoted as Tests A through I, as listed in the table. For each source area or test, URS collected several, usually three, flux chamber samples. The exceptions being Test D, from the surface of the water in the CDF where no sheen was evident where two samples were collected and from Test F, at the dredge moon pool, where two pairs of samples were collected. Each flux chamber measurement is provided in Table 4-1. Where appropriate, the average flux measurement for the test was calculated and is also provided. Samples of source material from each test were composited by Foster Wheeler with the results shown in the column preceding the individual flux chamber results.

Calculated emissions were somewhat variable and do not appear to directly correlate with source material concentrations. There is likely to be a high degree of variability inherent in the sampling methods and source media concentrations. Conclusions that can be drawn relative to emissions sources based on available data are discussed below.

4.4.1.1 CDF Emission Flux Results

Emissions from exposed sediments in the CDF were identified as a concern during previous dredging operations, especially associated with the Hot Spot dredging and temporary storage. During the Hot Spot removal, the CDF was covered with a liner, making maneuverability of the dredge discharge line and subsequent cover maintenance difficult. Emissions from the CDF during this PDFT study were of interest to evaluate potential options other than a cover for managing emissions, such as water and/or surfactants, to provide input to the dispersion modeling being conducted for developing ambient air action levels for future work, and to compare with other sources of emissions for use in overall management of site activities. The results from the flux chamber sampling are summarized in Table 4-1.

Based on the data provided in Table 4-1, it appears that disturbed sediment and associated sediment/water mixtures at the CDF have the highest emission flux. Emission rates calculated from raw sediment and from sediment with a thin water cover ranged from 666 to 4,090 nanogram per meter^2 minute (ng/m^2-min) with an average of approximately 2,500 ng/m^2-min. Results from inside the boom area in the CDF where a sheen was visible had a slightly smaller range (1,320 to 3,320 ng/m^2-min) also with a calculated average of 2,500 ng/m^2-min. from three tests. URS calculates the area inside of the boom to be approximately 2,000 square feet (ft^2) (190 m^2). Based on the highest emission rate calculated (4,090 ng/m^2-min) for fresh sediment discharged to the CDF, the resulting emission from the surface area inside the boom would be approximately 1.1 gram of total PCB per 24 hour day. Flux chamber data from the area around the boom and the area without a sheen indicate that these surfaces are also a source of significant emissions. URS calculates the surface of Cell #1 as 8,900 m^2 (96,000 ft^2), with an emission rate of 1,430 ng/m^2-min (collected 25 ft. away from sheen), this calculates as a total emission rate of 18 grams per day of total PCBs.

The available data indicate that a shallow (2 in.) water layer and/or the presence or absence of a sheen do not significantly alter the calculated emissions. The average emissions from the CDF surface at a distance from the sheen (Test D) had slightly lower average emissions (1,355 ng/m^2-min) than those calculated near the dredge discharge pipe and from the sheen area. However, note that the individual results were well within the range of emissions calculated for the other CDF sources.

Flux chamber measurements were also taken of the area inside the CDF boom following the application of three surfactants, Dawn dishwashing liquid, commercially available dispersant Biosolve, and Simple Green. Results from the Dawn and Biosolve indicate that the surfactants may not be effective at reducing emissions, and may actually increase the emissions from the surface of the CDF. The result from the Simple Green is somewhat less than most of the other measurements taken at the CDF (925 ng/m^2-min).

However, it is within the range of the lower emissions measurements calculated from raw sediment and the sediment/water mix and may be within the error of the field measurements.

4.4.1.2 Flux Chamber Results from Dredging Operations

Emission measurements from the dredge indicate that slightly elevated emission fluxes are generated from the moon pool at the dredge. The average of the pair of highest emissions was approximately 915 ng/m^2-min, approaching the lower emission fluxes calculated at the CDF. Based on a surface area of approximately 915 ft^2 (85 m^2), the total emissions from the moon pool calculate to approximately 100 mg/day or 0.1 gram per day. Flux chamber results from outside the silt fence averaged 213 ng/m^{2-}min indicating that the silt fence may be effective at confining the higher emissions within a relatively small surface area.

Another potential source of PCB emissions is the grizzly and hopper on the dredge. Because it was physically impractical to collect flux chamber measurements from the grizzly (a given surface area could not be isolated), headspace measurements were collected by drawing air from the grizzly through the XAD resin. Headspace readings ranged from 2,070 to 6,100 ng/m^3 total PCBs. URS estimates that based on a hopper volume of 72 m^3 and an air exchange rate of one hopper volume every 15 minutes, the emission rate would be approximately 20 μg/min or 0.03 grams of PCB per 24 hour day. Note that if the size of the hopper were significantly increased during full scale operations, the emissions would also increase accordingly.

4.4.1.3 Flux Chamber Results from Mudflats

Flux chamber samples were also collected from the mudflats north of Wood Street on the Acushnet side of the harbor. The locations were chosen as known areas of elevated PCB concentrations based on earlier harbor delineation sampling. Flux chamber samples and corresponding surface grab samples of sediment were collected from locations URS-W1, URS-W2, and URS-W3, corresponding to previous sampling locations identified as S-657, S-602, and S-650, (designated sequentially in order of sampling and composited over a one-foot interval) respectively. Sampling locations are shown on Figure 4-3. It is generally accepted that exposed mudflats at low tide are a primary source of ambient air PCB concentrations, which range from approximately 10 ng/m^3 to over 100 ng/m^3.

Flux sampling chambers were placed near or at previously sampled locations and surface grab samples of the sediment from the mudflats were also collected in association with the flux chamber sampling. Results from the flux chamber and source material samples are included in Table 4-1 (Test I). For reference, the results from the harbor delineation sampling program for these locations (S-657, S-602, and S-650) are also included in Table 4-1. Sediment sample results from the two sampling events are in reasonably consistent agreement given the known field variability in this area. Note that source media samples of sediment from the discharge pipe collected from Tests A and B were reported on a wet weight basis, if corrected for 10 percent solids, results would be approximately 140 and 180 ppm on a dry weight basis. These results are similar to the 99 and 210 ppm dry weight results from two of the source samples from Test I and suggest that the material dredged during the test had PCB concentrations generally consistent with those in portions of the mudflat areas of the harbor. Emission flux measurements from the mudflat area ranged from 63 to 600 ng/m^2-min, less than those measured from sediments and sediment water/mixtures at the CDF. These data suggest that despite elevated PCB concentrations, *in situ* sediments and mudflats do not provide the same magnitude of emission fluxes as recently well mixed sediments exposed in the CDF. It is important to note that despite the lower emission flux from the mudflat areas, the total exposed surface area is approximately 40 acres. Therefore, the total emissions in grams per day would be greater than from the CDF.

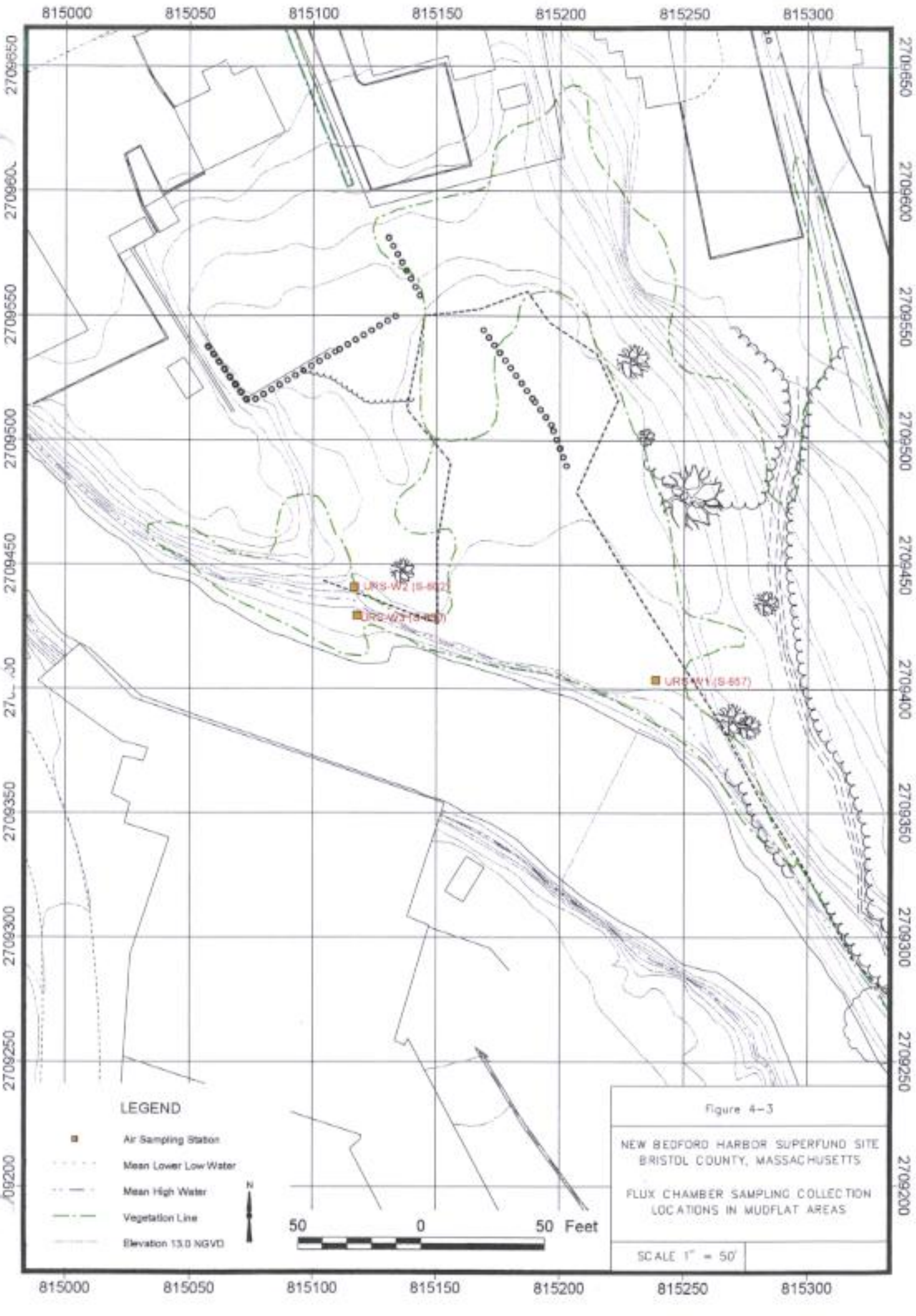


Figure 4-3

NEW BEDFORD HARBOR SUPERFUND SITE
BRISTOL COUNTY, MASSACHUSETTS

FLUX CHAMBER SAMPLING COLLECTION LOCATIONS IN MUDFLAT AREAS

The limited amount of flux chamber sampling conducted during this test is insufficient to conclusively determine that sediment/mudflat PCB concentrations significantly affect the magnitude of emission flux, although, the available data suggests that this is the case. No attempt was made to estimate the area of exposed mudflats or the varying emission fluxes associated with differing concentrations and tidal variations. However, it is noted that the area of the exposed mudflats at low tide is larger than the planned CDFs. Ambient air PCB concentrations measured during the baseline study (Foster Wheeler *Final Annual Report Baseline Ambient Air Sampling and Analysis*, March 2001) and referenced below are primarily attributed to emissions from exposed mudflats, and the river/harbor water surface.

4.4.1.4 Flux Chamber Summary

In summary, limited flux chamber sampling during the PDFT provided useful data for evaluating relative emissions from various sources. Some key findings are summarized as follows:

- Emission flux measurements do not correlate well with source material concentrations. However, they do generally appear to be the highest in association with well mixed sediment and water slurries in the CDF.
- *In situ* sediments in the mudflat area do not provide the same magnitude of emission flux per square area as well mixed sediment in the CDF. However, given the large surface area of the exposed mudflats at low tide, these areas and exposed surface water will continue to be a significant source of ambient air concentrations of PCBs, as measured during the Baseline study.
- Total emissions, calculated as flux x surface area x time, are directly proportional to the amount of exposed surface area. Accordingly, exposed CDF surface area is a significantly greater source of emissions than dredging operations. The contaminated sediments in the mudflat areas and the river/harbor surface water remain the largest surface area sources of emissions.
- Dredging activities, including the grizzly, hopper, and disturbed sediments in the moon pool are relatively small sources of PCB emissions in comparison with the CDF because of their lower flux measurements and limited surface area.
- The use of surfactants Dawn and Biosolve to control the sheen at the CDF does not appear to be effective at controlling PCB emissions. These limited data suggest that Simple Green may be more effective than other surfactants although additional testing is recommended before drawing definitive conclusions.
- The silt curtain at the moon pool appears to be somewhat effective at containing disturbed sediment thereby reducing the surface area of higher concentration water and the associated emissions in the dredge area.

4.4.2 Ambient Air Sampling

Ambient air samples were collected on three days during this PDFT to document conditions during dredging and CDF filling operations. Because of the short duration of the test, and the fact that PCB health effects are long-term, data were collected to document conditions and to provide information for full-scale activities at a later date. Data were not used to compare with standards or action levels for this limited one week effort. The results from this study will be used in conjunction with the flux chamber results (discussed above) to support development of ambient air action levels, being conducted by Foster Wheeler under a separate task.

Ambient air samples were collected from four stations around Cell #1 (2, 3, 6, and 17), from station #9, located to the north across the cove from the CDF, and from station #27 on the eastern side of the harbor near the dredge. Figure 4-4 shows the air sampling station locations. Samples were collected for 24 hours on each of three days (sampling was started the mornings of August 15, 16, and 17, 2000) chosen based on those days with maximum dredge production rates and warm weather as representative of “worst case” conditions. Samples were analyzed for NOAA and WHO congeners and total PCB homologue groups. Meteorological data and sample results are included in Appendix L and summarized in Table 4-2.

Table 4-2
Summary of Pre-Design Field Test Ambient Air Data

Date	Prevailing Wind Direction	Average Temp. °F	Avg. Solar Radiation w· m2	Concentration of Total PCB Homologue Groups (ng/m3)						
Station ID:				2	3	3D	6	9	17	27
8/15/00	NNE	69	70	43	110	79	110	40	610	12
8/16/00	SW **	70	131	86	100	254*	13	26	17	42
8/17/00	NW	66	269	160	48	82	90	36	110	24
Average:				96	88	138	71	34	245	26

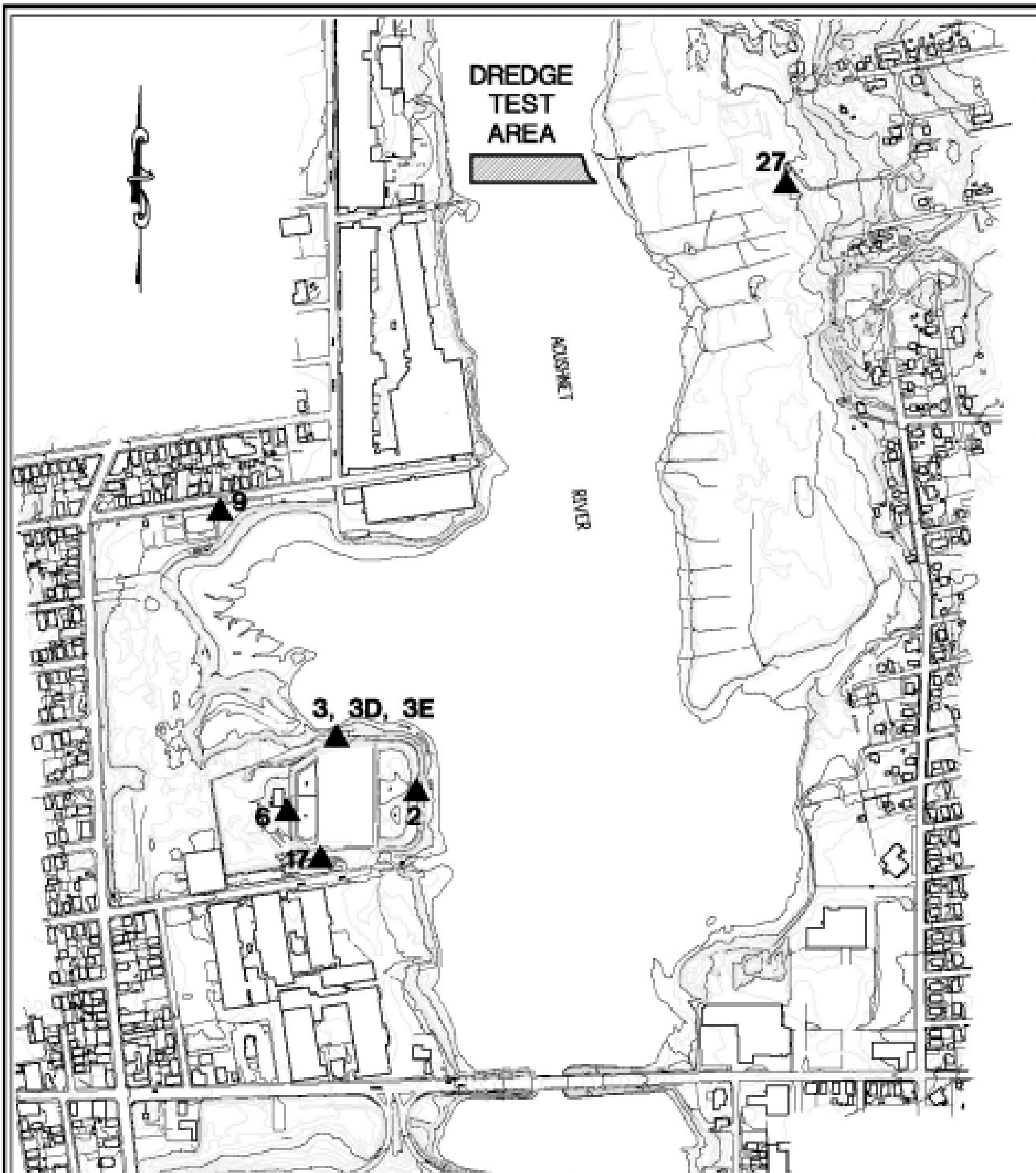
* Sample analyzed by government designated QA lab (80,000 ng / 315.225 m^3)

** See wind rose in Appendix L, wind was from the SW for most of the day (during dredging)

The highest total PCB concentration detected was at station #17 (610 ng/m^3), the station downwind from the CDF on August 15. Stations 3 and 6 also had detected concentrations above 100 ng/m^3 on August 15, 2000. High concentrations on other days ranged from 100 (as measured by the Foster Wheeler primary laboratory, 254 measured by the government QA laboratory) to 160 ng/m^3 at stations 3 and 2, respectively, with somewhat elevated concentrations ranging from 82 to 110 ng/m^3 at stations 2, 3, 6 and 17 on August 16 and 17. Results from stations 9 and 27, away from the CDF, had lower concentrations (less than 50 ng/m^3 on each day) and were also dependent on wind direction. These data support the premise that, other than background attributed to the mudflats and surface water, the primary sources of PCB concentrations in ambient air are due to emissions from CDF operations. Results from station 27 indicate that ambient concentrations were generally consistent with established baseline concentrations for the Acushnet Substation (summer and September 2000 averages ranged from 20 to 40 ng/m^3) (Foster Wheeler *Final Annual Report Baseline Ambient Air Sampling and Analysis*, March 2001) and were not significantly adversely affected by dredging operations.

4.4.3 Odors

During the PDFT, Foster Wheeler conducted both Real-time and Personnel air monitoring. Personnel monitoring consisted of Indirect Analysis of samples taken on the Dredge barge and at the Sawyer Street facility for PCBs using NIOSH Method 5503. Samples taken were from Exclusion Zone (EZ) workers and from the EZ, Contaminant Reduction Zone (CRZ), and the Support Zone to determine if any PCBs were becoming airborne that could be detrimental to workers health. Real-time monitoring is direct monitoring using a Combustible/Toxic Gas Indicator (CGI) and a Photo-Ionization Detector (PID) both operating in the survey mode. The CGI detects the following gases in the atmosphere: Oxygen in the air from 0 to 100% - normal Oxygen is 20.9%. Lower Explosive Limit - a function of Flammable Gases in the Air - 0 to 100%; Carbon Dioxide (CO_2) -0-10,000 ppm; and H_2S, an asphyxiate and toxic gas 0 to 10,000 ppm.



KEY:

▲ AIR SAMPLING STATION LOCATION

FIGURE 4-4

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

PRE-DESIGN FIELD TEST AMBIENT AIR SAMPLING LOCATIONS

SCALE: AS SHOWN

CADDFILE: NBH_017a.DWG

On August 18, 2000 both Real Time and Personnel monitoring were being conducted at the Sawyer Street facility. In the Exclusion Zone at the sediment discharge line, an H_2S odor was detected. Readings were taken upwind and downwind of the discharge and no H_2S readings were found upwind (South) of the discharge pipe. Downwind of the discharge pipe readings indicated a maximum H_2S percentage of 7 ppm out to a distance of ten ft. downwind of the discharge pipe. Readings taken 15 ft. downwind of the discharge pipe showed 0 ppm for H_2S. All other parameters of the CGI and PID were 0 or background in the Exclusion Zone. Real-time readings conducted on the Dredge barge using the PID and the CGI all showed 0/background during the sediment dredging.

Real time monitoring was conducted at the Sawyer Street site - in all work areas, EZ perimeter, CRZ and the Support Zone/trailer compound. All CGI and PID readings were 0/background. The area North of the EZ by the cove, north of the site, was checked extensively due to the discernable H_2S odor on that particular day, all readings on the CGI and PID were 0/background downwind outside the EZ in this area.

All Indirect Air Sampling (Personnel Monitoring) results received from ESA laboratories showed PCBs at below detection Limits for the entire Dredge Study, this included several samples from downwind of the discharge area at the Sawyer Street site.

During full scale dredging operations, engineering controls will be used to the extent practicable to control the potential for odors.

5.0 WASTEWATER TREATMENT

Dredging operations conducted as part of the PDFT resulted in the generation of wastewater requiring treatment before final discharge to the harbor. The volume of wastewater generated during the PDFT was minimized by the use of a water recirculation system from CDF Cell #2 to the dredge SPU. Wastewater generated during the PDFT would be representative of wastewater generated during full-scale dredging using a Bean type hydraulic excavator. In an effort to test the performance of the equipment and processes proposed for a full-scale wastewater treatment system, a pilot-scale wastewater treatment system was used to treat the wastewater generated during the PDFT. The system was operated from September 4, 2000 through October 13, 2000 to treat over 1-million gallons of wastewater.

5.1 Objectives

The objectives of the pilot-scale wastewater treatment were to: 1) evaluate the treatment efficiency, flexibility and reliability of the individual unit operations/processes proposed in the Wastewater Treatment Plant (WTP) design; and 2) confirm the findings of the wastewater treatability studies. The individual unit operations that were evaluated in the pilot-scale treatment included:

- Chemical Addition and Settling;
- Ultrafine (0.45 µm nominal) Sand Filtration;
- Granular activated carbon adsorption;
- UV/Oxidation; and
- Dewatering with a plate and frame filter press.

5.2 Process Description

The pilot-scale wastewater treatment system was operated from September 4, 2000 through October 13, 2000 and treated approximately 1 million gallons of water generated during the dredging field test. The treatment system consisted of chemical addition (aluminum sulfate (alum), polymer) and settling using an inclined plate clarifier, ultra-fine (<0.45 µm nominal) sand filtration, UV/oxidation, and/or GAC adsorption. Portions of the existing WTP were utilized to conduct the pilot scale tests and the existing UV/Oxidation system was also evaluated using the ultrafine filtration system. The layout of the Sawyer Street facility and pilot scale treatment system are shown in Figures 5-1 and 5-2, respectively. A more detailed description of the pilot tests individual unit processes is provided in the following sections.

5.2.1 CDF Cell #1

Sediments dredged during the PDFT were discharged to CDF Cell #1. The resulting supernatant was then pumped from the CDF Cell #1 to CDF Cell #2 using a portable pump located at the site. In order to control the concentration of TSS within the supernatant, flexible hose and adjustable piping were used to pump water from varying depths within the cell. The concentration of PCBs within the dredged sediments ranged from 0 to 2,700 milligrams per kilogram (mg/kg).

5.2.2 CDF Cell #2

CDF Cell #2 was utilized as an equalization basin prior to the wastewater being pumped to the inclined plate clarifier. Utilizing CDF Cell #2 eliminated any mixing effects that could occur as the dredged slurry was discharged into CDF Cell#1 and provided for a more consistent and representative wastewater stream entering the pilot-scale treatment system.

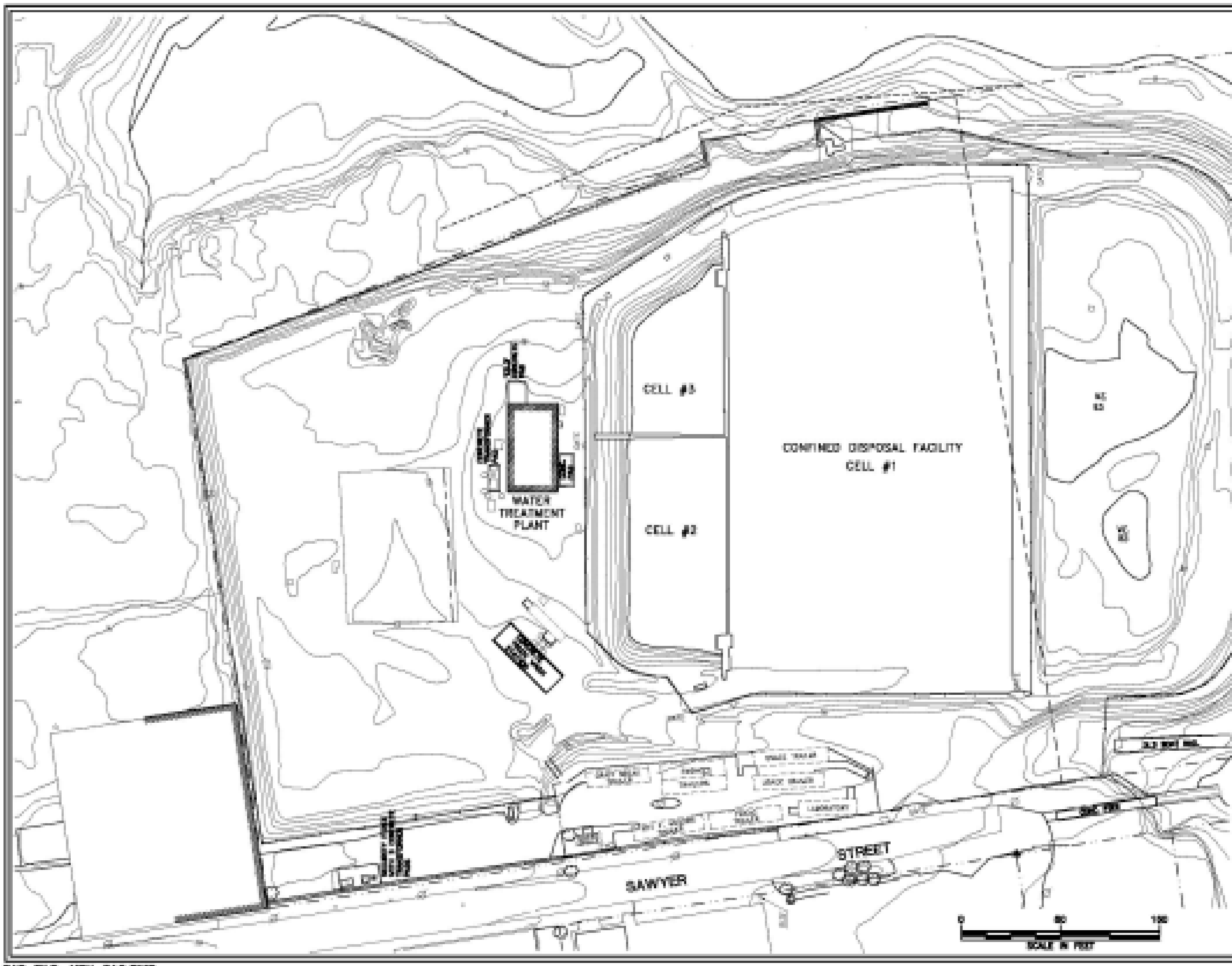


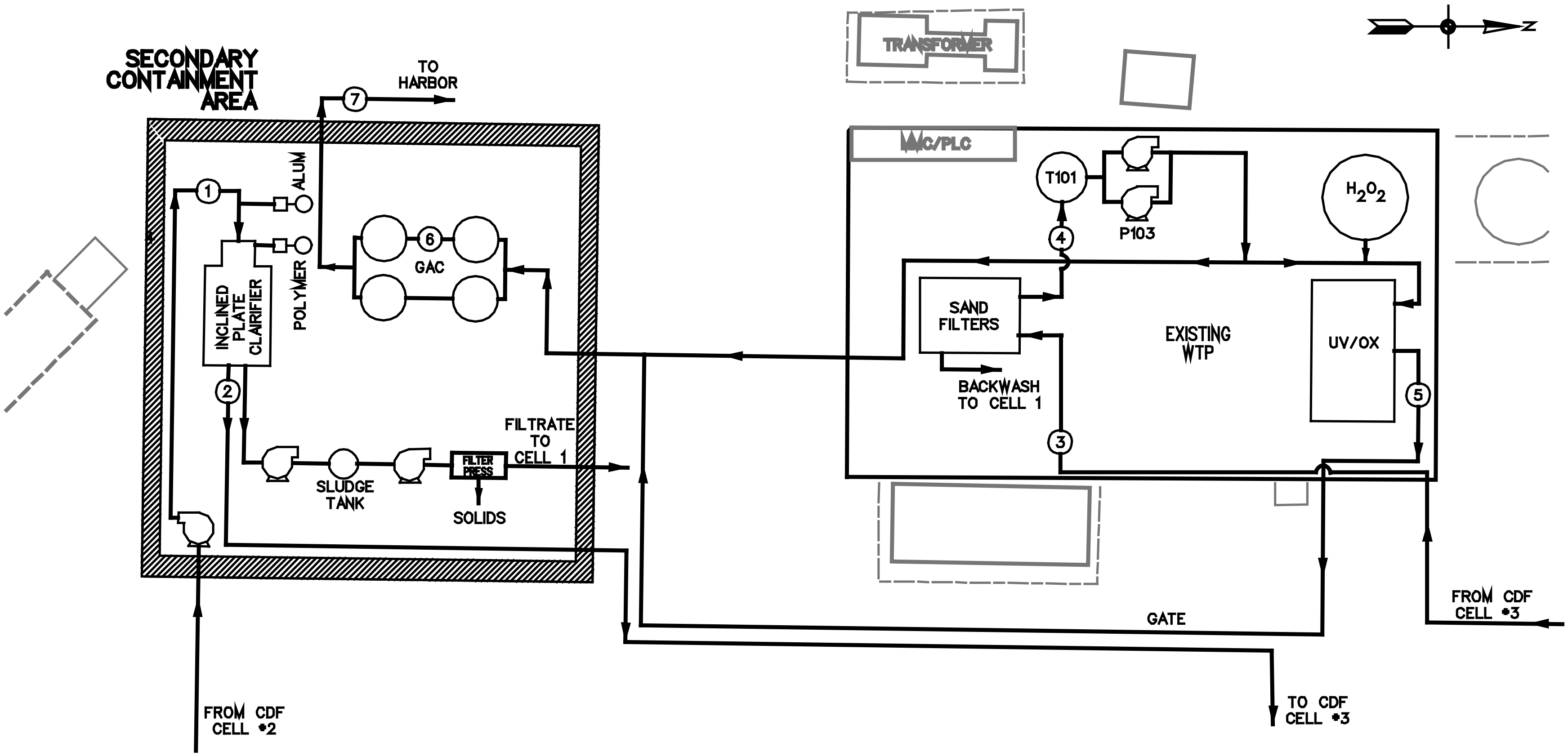
FIGURE 5-1

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

SAWYER STREET LOCATION
SITE LAYOUT PLAN

SCALE: AS SHOWN

CAD FILE: NBH_016.DWG



STREAM #	DESCRIPTION
1	CLARIFIER INFLUENT
2	CLARIFIER EFFLUENT
3	SAND FILTER INFLUENT
4	GAC/UV/OXIDATION INFLUENT
5	UV/OXIDATION EFFLUENT
6	GAC MIDPOINT
7	GAC EFFLUENT

FEET
10 0 20 40
SCALE 1"=20'

FIGURE 5-2

NEW BEDFORD HARBOR SUPERFUND SITE
NEW BEDFORD, MASSACHUSETTS

PILOT SCALE SITE LAYOUT

SCALE: NOTED

17ec101f.dgn

5.2.3 Chemical Addition/Settling

An inclined plate clarifier (Parkson Lamella Gravity Settler Model LGS 570/55) was obtained from the Charles George Superfund site (Tyngsboro, MA). The clarifier, which has 456 ft^2 of clarification area and 114 ft^2 of thickening area, was operated at 100 gallons per minute (gpm) (0.22 gpm/ft^2). Both alum and polymer were added inline to the influent wastewater before the clarifier flash mix tank.

Clarified effluent gravity flowed into CDF Cell #3. Flocculent that was formed in the flash and slow mix tanks settled to the bottom of the clarification tank where it accumulated as a sludge. The sludge was pumped to a sludge holding tank for dewatering with a diaphragm plate and frame filter press or back to CDF Cell #1.

5.2.4 CDF Cell #3

CDF Cell #3 was utilized as an equalization basin for the filtration and tertiary treatment systems. Due to the flowrate differential between the clarification and filtration processes, influent water to CDF Cell #3 accumulated at 100 gpm for the first several days of the study. Once approximately 200,000 gallons of wastewater had been collected in CDF Cell #3, the existing sump pumps (P-102 AB) were used to pump the water at 165 gpm (minimum) through an ultrafine (0.45 μm nominal) sand filtration unit and subsequently to the UV/Oxidation system and/or the GAC polishing units. The CDF Cell #3 pumps were operated for approximately 10 hours per day. The increase in the effluent flowrate (100 gpm vs. 165 gpm) was necessary due to the minimum flowrate requirement (165 gpm) of the existing WTP.

5.2.5 Ultrafine Sand Filtration

The ultrafine sand filtration unit was rated for 0.45 μm nominal filtration and was sized to reduce the TSS from 30 mg/L (ppm) to less than 5 ppm. The sand filter was operated at a flowrate of 225 gpm. Approximately 55-60 gpm was continuously recirculated through the filter in order to achieve optimal filtration performance. This is equivalent to the one-quarter recycle rate specified in the proposed full-scale treatment system. Backwashing was conducted with potable water once per 12 hour day at approximately 50 gpm for 8 minutes per vessel. All backwash water necessary for the periodic cleanout of the sand filters was returned to CDF Cell #1.

5.2.6 Granular Activated Carbon

Four vessels (2 sets of 2 carbon vessels in parallel) each filled with 2,500 lbs of 8x30-mesh granular activated carbon were placed in service immediately after the ultrafine sand filtration to ensure compliance with the discharge criteria. These GAC vessels were capable of treating a flowrate of 220 gpm, however they were normally operated at a flowrate of 165 gpm. The effluent from the GAC was then discharged to harbor.

5.2.7 UV/Oxidation

After completion of the first six days of pilot testing using the GAC treatment system, the existing UV/Oxidation unit was used to treat the wastewater for an additional five days at a flowrate of 165 gpm (minimum). To ensure that the effluent from the UV/Oxidation unit met the OU#1 discharge standards, the treated wastewater was passed through the four GAC vessels for final polishing prior to discharge to the harbor.

5.2.8 Plate and Frame Filter Press

A Netzsch 470-millimeter (mm) plate and frame membrane filter press was used to dewater sludge generated in the Lamella clarifier. At regular intervals, the sludge was removed from the clarifier and transferred to a sludge holding tank. Once a sufficient quantity had accumulated, the sludge was chemically conditioned and mixed to enhance flocculation. The conditioned sludge was then pumped from the holding tank to the filter press at 100 pounds per square inch gauge (psig) to 150 (psig). As sludge was fed to the press, water was forced through the filter cloth producing a dewatered cake. At the end of the feed cycle, indicated by a low filtrate output, the blowdown phase began. The blowdown process cleared sludge from the influent ports by forcing compressed air through the lines. After blowdown had finished, the membrane plates were pressurized to 225 psig as a final squeeze to remove additional water from the cake. The last step of the process was to remove the dewatered cake after releasing pressure from the plates. All dewatered cake was placed in storage containers for disposal.

5.3 Results

Water samples were collected before and after each of the unit processes. These grab samples (which were collected daily) were analyzed for TSS, PCBs, total and dissolved metals (cadmium, chromium, copper and lead). Water samples for on-site field measurement of turbidity, pH and temperature were also collected several times each day. In addition, flowrate and pressure data was also recorded. A summary of the contaminant removal rates for turbidity, PCBs, and copper for each of the treatment processes is presented in Table 5-1. Only PCBs and copper are presented in Table 5-1 because they were the only contaminants detected above the discharge limits in the influent stream. The chemical and physical treatment results for each of the unit processes is discussed in more detail in the following sections.

Turbidity values in Table 5-1 are an average of the daily average turbidity while PCBs and copper values are an average of the daily measurement. Throughout pilot-scale treatment, Aroclor-1242 was the only Aroclor detected in the laboratory PCB analyses. The complete analytical results and total flows are provided in Appendix M.

TSS data did not indicate substantial removal of suspended solids from any of the treatment processes including sand filtration. Further investigation indicated some difficulty with laboratory analysis for TSS due to elevated levels of salts present in the samples. For this reason, field turbidity measurements were taken to be a more accurate indicator of suspended solids removal throughout pilot-scale treatment. Turbidity measurements are provided in Appendix M.

5.3.1 Chemical Addition and Settling

Two different coagulants (alum and Aquapure SC) and one anionic polymer (Aquapure FW) were utilized to remove suspended solids during the pilot scale treatment. Chemicals and dosages were selected based on the results of treatability testing. In addition, initial jar testing was conducted at the beginning of pilot-scale treatment to insure optimal dosage rates. In order to form a flocculent, either a 50% solution of Aquapure SC (Hubard-Hall, Inc), an alum coagulant with a slight cationic charge, or a 48% solution of alum was added to the wastewater stream at 100-150 mg/L. To enhance the settlability of the flocculent a 0.5% solution of Aquapure FW, a high molecular weight anionic polymer, was added at a dosage of 2-4 mg/L. The average turbidities entering and exiting the inclined plate clarifier were 16.15 NTU and 6.23 NTU, respectively. The average concentration of PCBs was reduced slightly from 7.03 micrograms per liter (µg/L) to 6.03 µg/L. The total copper concentration was reduced across the clarifier from an average of 18.64 µg/L to 9.4 µg/L while dissolved copper was reduced from 10.48 µg/L to 7.37 µg/L.

Table 5-1
Summary of Pilot-Scale Treatment Results
Average Turbidity, PCBs and Copper Concentrations

Stream #	Unit Operation/Process	Turbidity (NTU)*	Total PCBs (mg/L)	Dissolved Copper (mg/L)	Total Copper (mg/L)
1	Clarifier Influent	16.15	7.03	10.48	18.64
2	Clarifier Effluent/Cell #3 Influent	6.23	6.03	7.37	9.4
3	Cell #3 Effluent/Sand Filtration Influent	1.03	1.26	7.87	8.65
4	Sand Filtration Effluent/ GAC UV/oxidation Influent	0.48	0.94	16.43	14.98
5	UV/oxidation Effluent	0.5	< 0.065	15.0	17.4
6	GAC Midpoint	NM	< 0.065	<3.0	3.79
7	GAC Effluent	0.15	< 0.065	< 3.0	< 3.0

* NTU – Nephelometric Turbidity Units
NM – No measurement

The effluent from the Lamella clarifier was gravity fed to Cell #3 where additional settling and clarification took place. The turbidity was reduced from 6.23 NTU to 1.03 NTU. PCBs were reduced from 6.03 µg/L to 1.26 µg/L. Only a slight reduction in total copper and no reduction in dissolved copper was observed in CDF Cell #3. The existing sump pumps in CDF Cell #3 were then used to pump the wastewater through the remainder of the pilot-scale treatment system. Contaminant reduction rates for the Lamella clarifier and CDF Cell#3 are presented in Table 5-2.

Table 5-2
Chemical Addition/Settling Contaminant Reduction Rates

Sample Location	Average Turbidity (NTU)	Average Total PCBs (mg/L)	Average Copper Concentration	
			Dissolved (mg/L)	Total (mg/L)
Clarifier Influent, SP1	16.15	7.03	10.48	18.64
Clarifier Effluent, SP2	6.23	6.03	7.37	9.40
Cell #3 Effluent, SP3	1.03	1.26	7.87	8.65

Sludge production in the Lamella clarifier was measured by collecting 1-liter samples from the flash mixing tank. The samples were placed in a 1-liter Imhoff Cone and allowed to settle for a period of time until a distinct sludge layer developed. The volume of the sludge layer ranged from 38 ml to 55 ml and varied slightly with chemical and dosage. The volume can be extrapolated to determine sludge removal rates as a percentage of the overall process flow ranging from 3.8% to 5.5%.

After initial start-up of the Lamella clarifier, significant problems with the settling of the sludge were encountered due to the presence of Algae in Cell #2. Although the effluent quality remained clear, most of the sludge produced floated to the top of the Lamella clarifier. Periodic shutdown of the Lamella clarifier was necessary to remove this floating sludge. On September 9, 2000, operation of the Lamella clarifier was stopped so that Tolcide PS-200, an algaecide, could be added to Cell #2. On September 11, 2000 the Lamella clarifier was restarted with no evidence of any floating sludge. Tolcide PS-200 was added on an as-needed basis thereafter.

5.3.2 Ultrafine Sand Filtration

The Vortisand filter was operated from September 14, 2000 through September 29, 2000. For that period, the Vortisand filter influent turbidity averaged 1.03 NTU and the effluent turbidity averaged 0.48 NTU. This represents a 53% reduction in turbidity. The average concentration of PCBs was reduced slightly from 1.26 µg/L to 1.14 µg/L. An unexpected increase in the concentration of total and dissolved copper was noted across the Vortisand. This increase was consistent throughout the test period and is presently unexplainable. Results of the ultrafine sand filtration PCB and copper influent and effluent analyses are shown in Table 5-3.

Table 5-3
Ultra Sand Filtration Contaminant Reduction Rates

Sample Location	Average Turbidity (NTU)	Average Total PCBs (mg/L)	Average Copper Concentration	
			Dissolved (mg/L)	Total (mg/L)
Sand Filtration Influent, SP3	1.03	1.26	7.87	8.65
Sand Filtration Effluent, SP4	0.48	0.94	16.43	14.98

5.3.2.1 Additional Performance Testing of the Vortisand Filter

Due to the relatively low influent levels of turbidity observed at the influent to the Vortisand filtration units, additional performance testing of the Vortisand filtration with higher levels of influent turbidity was conducted on October 4 and 5, 2000. The piping of the pilot-scale system was changed so that water from Cell #2 could be pumped directly to the Vortisand filter, followed by tank T101, activated carbon, and discharged to Cell #3. On October 4, 2000, turbid water from Cell #1 was pumped to Cell #2 in order to increase turbidity levels in Cell #2. Water from Cell #2 was continuously recirculated during the performance testing. Water of varying levels of turbidity was pumped from Cell #2 to the Vortisand filters. Influent turbidity levels ranged from 2.9 NTU to 65.5 NTU. Turbidity removal rates ranged from a low of 16% to a high of 69%.

On October 5, 2000, additional testing was conducted in order to determine the performance of the Vortisand filters operating with more consistent turbidity levels. Less water with lower turbidity levels was pumped from Cell #1 to Cell #2. Continuous recirculation of the water continued within Cell #2 and was maintained at the same rate as the previous day. Influent turbidity levels ranged from 7.4 NTU to 8.0 NTU. Turbidity removal rates ranged from 32.5% to 39.2%. The results from October 4 & 5, 2000 are presented in Table 5-4.

Table 5-4
Vortisand Filtration Performance Testing
October 4 & 5, 2000

Date	Average Influent Turbidity (NTU)	Average Effluent Turbidity (NTU)	Difference (NTU)	% Removal
October 4, 2000	25.8	10.4	15.4	40.9
October 5, 2000	7.8	5.0	2.8	35.6

Samples of the influent and effluent from the Vortisand filter were collected on October 5, 2000 and filtered through 0.45 µm nominal and 1.0 µm nominal capsule filters in an attempt to quantify Vortisand filter performance. The Vortisand filters, rated at 0.45 µm nominal, reduced turbidity levels by 39% from 7.9 NTU to 4.8 NTU without any capsule filtration. However, filtration of the same influent water using a 1 µm nominal capsule filter reduced turbidity levels by nearly 88% from 7.9 NTU to 0.95 NTU and a 0.45 µm nominal capsule filter reduced turbidity levels by 99% from 7.9 NTU to 0.05 NTU. PCB concentrations were reduced 90% and 99% using the 1 µm and 0.45 µm capsule filters, respectively. The complete results are presented in Table 5-5.

Table 5-5
Capsule Filtration Results
October 5, 2000

Sample Location	Capsule Filtration	Turbidity (NTU)	PCBs (mg/L)
Influent	None	7.9	5.01
	1µM nominal	0.95	0.5
	0.45 µM nominal	0.05	<0.05
Effluent	None	4.80	4.24
	1µM nominal	0.93	0.34
	0.45 µM nominal	0.07	0.37

5.3.2.2 Vortisand Differential Pressures

Foster Wheeler contacted the manufacturer of the Vortisand filter for recommendations on how to increase the performance of the filters to achieve the 0.45 µm nominal rating. The manufacturer suggested adding polymer before the inlet to the filter as well as having the filter effluent flow directly to the activated carbon units in order to reduce the differential pressure across the filter. These changes were made to the system and additional Vortisand performance testing was conducted on October 11 and 13, 2000.

On October 11, 2000 the Vortisand filter was operated with the effluent flowing directly to the activated carbon units to reduce the differential pressure across the filter. A high differential pressure can cause the upper layer of fine sand, normally suspended, to become depressed reducing efficiency and causing the filter to operate more like a conventional sand filter. The normal operating differential pressure for the standard Vortisand filter set-up is 10-15 psig with the automatic backwash set at 15 psig. During the initial Vortisand filter set-up for pilot-scale treatment, the operating differential pressure was found to be higher (20 psig to 25 psig) requiring that automatic backwash be set to occur at 29 psig. All changes to the Vortisand filter operating parameters were conducted by the manufacturer, Sonitec Inc., during installation and startup. The high differential pressure was found to drop to 13 psig after the pilot-scale treatment piping was changed to allow the Vortisand filter to be fed directly from Cell #2. This indicates that the cause of the high differential pressures during operation was the size of pumps P-102A and B which were initially used to feed the Vortisand filter. After the piping change, the smaller pump formerly used to feed the Lamella clarifier was used to feed the Vortisand filter causing a drop in filter influent pressure of approximately 10 psig. Further changing the piping to allow the activated carbon to be fed directly from the Vortisand filter did not result in a change of differential pressure. Typical differential pressures encountered during pilot-scale treatment are presented in Table 5-6.

Table 5-6
Vortisand Filter Differential Pressures

Mode of Operation	Influent Pressure (psig)	Effluent Pressure (psig)	Differential Pressure (psig)
Vortisand filter fed from P-102	60-63	36-43	20-26
Vortisand filter fed from Lamella feed pump	51-54	36-42	13-15
Vortisand filter fed from Lamella feed pump with GAC directly in-line	54-55	38-42	13-14

No change in turbidity reduction rate was observed as a result of changes to the operating differential pressure of the Vortisand filter. In one case, a slight increase in turbidity was noted across the Vortisand filter. Influent turbidity levels for October 11, 2000 ranged from 2.75 NTU to 17 NTU and effluent turbidity levels ranged from 2.95 NTU to 6.4 NTU. Turbidity removal rates ranged from -7.3% to 62.4%.

5.3.2.3 Vortisand Filter Operation with Chemical Addition

According to the manufacturer, water from CDF cell #2 may have contained colloidal particles that carried a slight electrical charge. This charge can cause the ultra-fine suspended sand layer and the colloidal particles to repel each other thereby reducing the performance of the filters. This effect has been observed by the manufacturer in other applications where Vortisand filters have been used to filter surface water. Addition of a chemical polymer at the filter influent can reduce or eliminate the electrical charge of the colloidal particles thereby increasing the performance of the filter.

On October 13, 2000, the Vortisand filter was operated while adding chemicals before the filter influent according to the manufacturer's recommendation. Three different chemicals were tested including two coagulants and one anionic polymer. Aquapure SC, an aluminum salt coagulant with a slight cationic charge was mixed to 50% and added at 100 ppm. A 48% solution of alum was also tested at 100 ppm. A 0.5% solution of Aquapure FW, a high molecular weight anionic polymer, was added at 2-4 ppm. The performance of the filter with the addition of each chemical is presented in Table 5-7.

Table 5-7
Vortisand Performance with Chemical Addition
October 13, 2000

Time	Chemical	Influent (NTU)	Effluent (NTU)	% Removal
0900	None	9.1	6.0	34
0940	None	9.5	5.4	43
1015	Aquapure SC, 100 ppm	9.3	5.9	37
1055	Aquapure SC, 100 ppm	9.4	8.1	14
1245	48% Alum, 100 ppm	9.3	7.2	23
1415	Aquapure FW, 2-4 ppm	8.5	3.7	56
1445	Aquapure FW, 2-4 ppm	8.8	3.5	60
1515	Aquapure FW, 2-4 ppm	9.0	3.1	66

5.3.3 Granular Activated Carbon

Activated carbon treatment was conducted from September 15, 2000 through September 19, 2000. Four vessels (2 sets of 2 carbon vessels in parallel) each filled with 2,500 lbs of Envirotrol's EI-30 granular activated carbon. EI-30 is a virgin 8x30-mesh bituminous coal-based activated carbon. Analytical Data from these dates indicted influent total PCB concentrations ranging from 0.73 μg/L to 1.28 μg/L and an effluent PCB concentration less than the method reporting limit (MRL) of 0.05 μg/L per Aroclor for all samples taken. For the same period, the concentration of dissolved copper was reduced from 12-15 μg/L to <3.0 μg/L and the concentration of total copper was reduced from 12-18 μg/L to 4.4 μg/L.

No backwashing of the activated carbon vessels was required during pilot-scale testing and no operational problems with the activated carbon were encountered.

5.3.4 UV/Oxidation

The existing 270 kilowatt (kW) UV/Oxidation unit was operated September 25, 2000 through September 29, 2000. Analytical Data from September 27, 28, 29 indicated influent PCB concentrations of 1.24, 1.19 and 1.42 μg/L and effluent PCB concentrations less than the MRL of 0.05 μg/L per Aroclor for two of the three samples.

The calculated UV dose was 28.125 kWh/1,000 gal. based on a flowrate of 160 gpm. The calculated electrical energy per order (EE/O) was 19.97. This is slightly more efficient than the EE/O of 21.9 determined by Calgon Carbon Corporation in the November 1999 bench-scale testing.

Extrapolation of the EE/O to a full-scale 1,200 gpm system with an influent PCB concentration of 1.0 μg/L would require a total lamp power of 1,708 kW to reduce the PCB concentration below the 0.065 μg/L discharge limit. A 1,708 kW system would require the addition of four 360 kW units in addition to the existing 270 kW unit. This is slightly less than the 1,872 kW determined in the November 1999 bench-scale study which would require five 360 kW units in addition to the existing 270 kW unit.

Each system is sized for an influent PCB concentration of 1.0 μg/L and it is possible that neither UV/oxidation system would be capable of meeting the discharge criteria of 0.065 μg/L if the influent PCB concentration were to increase significantly above 1.0 μg/L. In addition, no reduction of total or dissolved metals can be expected with UV/Oxidation treatment based on this pilot-scale treatment.

5.3.5 Plate and Frame Filter Press

Ten test runs were performed on small volumes of chemically conditioned sludge ranging from 17 gallons to 47 gallons. Of the ten runs carried out, nine were completed. Test #2 was aborted due to sludge "bleed through". Bleed through occurs when sludge passes through the filter cloth into the filtrate flow. Low polymer dosage was likely the cause of the bleed through.

Polymer was added to increase the solids content of the cake produced from each filter press cycle. The polymer used throughout the tests was Aquapure FW or a combination of Aquapure FW with a small amount of Magnifloc added. The strength of the polymer solution ranged from 0.25% to 0.5% and the volume added ranged from 23L to 91L.

The filter press cycle time ranged from 84 minutes to 255 minutes. The operating time was divided into three segments; fill time, squeeze time, and cake release/maintenance time. The average time for each segment was 2 hours and 10 minutes, 25 minutes, and 30 minutes respectively. Fill and squeeze times were recorded based upon filtrate flow. At the end of each cycle, percent solids and other physical properties of the filter cake were measured.

The percent solids of the filter cake averaged 24%. The maximum and minimum percent solids of the cakes were 38% and 15% respectively. The solids content was determined by weighing the filter cake before and after drying. The density of the filter cake ranged from 68.6 lbs/ft^3 to 91.3 lbs/ft^3 the average density was 74 lbs/ft^3. Density was measured by first weighing a sample of the filter cake. The filter cake sample was then placed in a graduated cylinder of water. By dividing the weight by the volume of water displaced, the density was calculated.

The physical characteristics of the filter cake varied for each test. In certain tests, the filter cake was a well-formed solid, while in others it was thin and soft. Generally, the filter cake was described as having an uneven thickness. The lack of consistency amongst filter cakes can be attributed to the variation in polymer dosage and volume of sludge added. The filtrate however had minimal variance, it was usually a clear color. The volume of polymer added to achieve a 38% solids content cake was 5.3 gallons of a combination of a 0.5% solution of Aquapure FW and a 0.4% solution of Magnifloc, to 50 gallons of sludge.

Samples of the settled sludge, filtrate, and filter cake were sent off-site and analyzed for PCBs, TSS, and metals. Results of analytical tests are presented in Table 5-8.

Table 5-8
Summary of Filter Press Analytical Results

Location	TSS (mg/L)	PCB	Total Cadmium	Total Chromium	Total Copper	Total Lead
September 28, 2000 Sampling Data						
Settled Sludge	4,620	39.8 µg/L	NA	NA	NA	NA
Filtrate	NA	22.8 µg/L	ND:<5.0 µg/L	ND:<22.0 µg/L	27 µg/L	ND: <5.0 µg/L
Filter Cake	NA	35,000 µg /kg dry	0.74 mg/kg dry	200 mg/kg dry	200 mg/kg dry	74 mg/kg dry
September 14, 2000 Sampling Data						
Settled Sludge	7,800	13.0 µg/L	NA	NA	NA	NA

NA - Not analyzed
ND - Not detected

During the pilot-scale tests, minimal maintenance was required to the filter press. Occasionally the filter plates were washed to prevent blinding of the plates.

5.3.6 Effluent Toxicity Testing

In order to evaluate potential impacts of the treated wastewater effluent to aquatic receptors two sets of effluent toxicity tests were conducted by ENSR. Wastewater effluent from the pilot-scale treatment system using activated carbon was used for the first set of toxicity tests while the second test was performed with wastewater effluent generated by the pilot-scale treatment using UV/oxidation. Both sets of toxicity tests used mysid shrimp, sea urchin, and red alga as indicator organisms. In addition, several other parameters were measured including: (1) the concentration of Tolcide PS-200, an algaecide added to CDF Cell #2 for control of algae; (2) the concentration of hydrogen peroxide which is added to the UV/oxidation system; and (3) the concentration of metals including cadmium, chromium, copper and lead.

The results of the toxicity testing of the effluent from pilot-scale wastewater treatment using activated carbon did not indicate any toxic affects on any of the indicator organisms; however, adverse impacts on the reproductive systems of two of the three indicator systems were noted. No hydrogen peroxide was added when activated carbon was being used for wastewater treatment.

The results of the toxicity testing of the effluent from pilot-scale wastewater treatment using UV/oxidation did indicate acute toxicity in one indicator organism and chronic effects in the other two indicator organisms. Hydrogen peroxide in the UV/oxidation effluent was measured at 46 mg/L.

Neither PCBs, metals or Tolcide were detected above the detection limits in either set of toxicity tests. Refer to ENSR Corporation Document No. 9000-236-FOV, *Toxicological Evaluation of GAC and UV/OX Treatment Effluents to New Bedford Harbor CDF WTP Pilot Plant Testing*, December 2000, for detailed results (ENSR, 2000b).

5.4 Conclusions

The data collected indicates that the contaminants present within the wastewater are strongly associated with the suspended particles and by removing these suspended solids the majority of the contaminants can be removed from the wastewater stream. However, due to the source of the wastewater (seawater) there are colloidal particles present which flocculation, clarification and filtration alone cannot remove. The concentration of PCBs and copper associated with these colloidal particles is sufficient enough that the wastewater could exceed the discharge limits for OU#1. Therefore, tertiary treatment in the form of activated carbon will be required in order to achieve the discharge limits for OU #1.

5.4.1 Chemical Addition and Settling

The Lamella clarifier (Model LGS 570/55) was operated at 0.22 gpm/sq ft. during pilot-scale treatment. Based on testing of samples sent to the manufacturer during treatability testing, a loading rate of 0.7 gpm/sq ft. was recommended; however, this recommendation was based on a reduction of influent TSS from 159 ppm to less than 20 ppm TSS using alum, sodium hydroxide and anionic polymer. The performance of the Lamella clarifier was satisfactory in reducing turbidity levels to less than 4 NTU for the majority of pilot-scale treatment. Effluent turbidity was found to increase substantially if the sludge removal rate was not closely monitored due to the channeling and back-up of sludge into the inclined plates. Sludge removal during pilot-scale treatment was conducted by manual operation of an air operated diaphragm pump. For full-scale treatment, better control over sludge removal may be achieved by automating the sludge removal process with a timed sludge removal cycle. In addition sludge quality and sludge removal may be improved with a LGST model Lamella clarifier which incorporates an internal sludge thickening tank. The internal thickening tank will help to prevent channeling and produce a sludge with a higher percentage of solids. Sludge removal rates can be highly variable from day to day depending on influent TSS and chemical dosage rates. During full-scale treatment, the sludge production rate must be checked regularly to determine proper sludge removal rates.

The use of CDF Cell #3 as an additional settling basin after the Lamella clarifier consistently enabled the turbidity levels to be reduced to less than 1 NTU. This indicates that even under optimal performance conditions, a small amount of pin-floc may have been carried through the Lamella clarifier and into CDF Cell #3 where it subsequently settled out. Under full-scale treatment, CDF Cell #3 may be beneficial as a secondary settling basin to improve the quality of the wastewater.

5.4.2 Ultrafine Sand Filtration

The Vortisand sand filters did not achieve their rated filtration efficiency of 0.45-µm nominal in the manner they were operated during the pilot-scale treatment. Changes in the method of operation were attempted in order to increase the performance of the filter. Differential pressures across the filter were adjusted to prevent depression of the suspended sand layer of the filter. In addition, chemicals were injected just prior to the Vortisand filter influent to neutralize charged colloidal particles. Limited data from these tests indicated that the filtration performance increased to as high as 66% reduction in turbidity with the addition of an anionic polymer. Further testing of chemical addition and differential pressure adjustment may prove successful in achieving better filtration performance, however, it is not expected that the 0.45-µm nominal rating will be attainable using these methods. In addition to the 0.45 µm nominal rating of the Vortisand filters, other beneficial features of the system include a reduced footprint as well as a lower backwash flow than most other sand filters.

Due to the fact that the Vortisand filter performed more like a conventional sand filter, other filtration methods may be evaluated for full-scale treatment. Sand filtration alone may not be capable of achieving the desired filtration efficiency. In order to achieve greater filtration efficiency, some type of cartridge or bag filters in place of or in addition to sand filtration will be required.

5.4.3 Activated Carbon

Activated carbon was successful in reducing the concentration of PCBs to below the discharge limit of 0.065 µg/L per Aroclor. In addition, activated carbon reduced the concentration of total and dissolved metals, most notably copper. Although activated carbon is especially known for its ability to remove organic contaminants, its ability to remove low levels of inorganic ions has also been documented.

No operational problems with activated carbon were encountered during the pilot-scale treatment. Over 1-million gallons were treated through the activated carbon without any need to backwash. In addition breakthrough of the primary GAC vessels was not detected. Based on the GAC usage rate of 3,500 gallons wastewater per pound of GAC, breakthrough would not be expected until approximately 17 million gallons have been treated through the primary GAC vessels.

An activated carbon column test to determine GAC usage was not conducted as part of the pilot-scale treatment. For an accurate determination of GAC usage the test column would need to be sized to replicate the characteristics of a full-scale system. This would entail continuous operation of the column for potentially as long as 2 months. Data from the micro-column test conducted during treatability testing will be used for full-scale system sizing calculations.

5.4.4 UV/Oxidation

The 270 kW UV/oxidation unit was successful in reducing the concentration of PCBs to below the discharge criteria of 0.065 µg/L per Aroclor. Based on the influent and effluent concentrations, the UV/oxidation EE/O was calculated to be 19.97, slightly more efficient than EE/O of 21.9 calculated in previous bench testing conducted by Calgon in December 1999.

Extrapolation of the EE/O to a full-scale 1,200 gpm system with an influent PCB concentration of 1.0 µg/L would require a total lamp power of 1,708 kW to reduce the PCB concentration below the 0.065 µg/L discharge limit. A 1,708 kW system would require the addition of four 360 kW units in addition to the existing 270 kW unit. This is slightly less than the 1,872 kW determined in the November 1999 bench-scale study which would require five 360 kW units in addition to the existing 270 kW unit. UV/oxidation system sizing calculations are presented in Appendix M.

Each system is sized for an influent PCB concentration of 1.0 μg/L and it is possible that neither system would be capable of meeting the discharge criteria of 0.065 μg/L per Aroclor if the influent PCB concentration were to significantly increase above 1.0 μg/L. In addition, no reduction of total or dissolved metals can be expected with UV/Oxidation treatment based on this pilot-scale treatment.

5.4.5 Plate and Frame Filter Press

Based upon the results of pilot-scale treatment, dewatering can reduce the water content and volume of sludge generated from the wastewater treatment process. The size of a full-scale dewatering system will depend upon the wastewater flowrates and system's operating hours. Chemical conditioning of the sludge is recommended to increase the solids content of the cake and system efficiency.

Assuming the sludge dewatered during the pilot-scale tests is representative of the sludge to be treated, the table shown below can be used as a guide for sizing a filter press based upon wastewater flowrates. Sizing of the filter press system is based upon operating the filter press for 8-hours per day, and one cycle per day. For each wastewater flowrate, a Netzsch filter press or equivalent is specified based upon the filter cake capacity required. System sizing calculations are presented in Table 5-9.

Table 5-9
Required Filter Press Capacity for Varying Wastewater Flowrates

Wastewater Flowrate (gpm)	Total Solids (lbs/day)	Total Weight of Filter Cake (lbs/day)	Filter Press Volume Required (ft^3)	Netzsch Unit Recommended		
				Model #	# of Units Required	Capacity of System (ft^3)
100	277.42	1,109.69	15.0	630-III	1	20
125	346.78	1,387.11	18.7	630-III	1	20
150	416.13	1,664.53	22.5	800-I	1	30
300	832.27	3,329.06	45.0	800-III	1	50
450	1,248.40	4,993.59	67.5	1200-II	1	88
600	1,664.53	6,658.12	90.0	1200-III	1	110
750	2,080.66	8,322.65	112.5	1200-IV	1	134
900	2,496.80	9,987.18	135.0	1200-V	1	155
1,050	2,912.93	11,651.71	157.5	1500-III	1	172
1,200	3,329.06	13,316.24	179.9	1500-IV	1	200
1,350	3,745.19	14,980.78	202.4	1500-V	1	229
1,400	3,883.90	15,535.62	209.9	1500-V	1	229

5.4.6 Effluent Toxicity Testing

Two sets of toxicity tests were conducted to evaluate potential impacts of the treated wastewater effluent to aquatic receptors. The first set of tests were performed using effluent from activated carbon treatment and did not indicate any toxic affects on any of the indicator organisms, however, adverse impacts on the reproductive systems of two of the three indicator species were noted. The second set of tests were performed using effluent from UV/oxidation treatment and did indicate toxicity in one indicator organism and chronic effects in the other two indicator organisms.

In both sets of toxicity tests, PCBs and metals were not measured above the detection limits. Since the detection limits for the metals are comparable to the levels of the ambient water quality criteria for protection of aquatic life, it can be assumed that any observed toxicity was not likely due to these constituents.

Tolcide was not measured above the detection limit of 5 mg/L in either toxicity test, however, the concentration that the literature indicates may have some effect on the test organisms is 2.5 mg/L. Although the dosage and biodegradability of Tolcide suggests that it would rapidly dissipate in the environment following application, effects from this constituent cannot be ruled out. If Tolcide did have any effects they would be consistent in both sets of toxicity tests.

Wastewater treatment using UV/oxidation requires the addition of hydrogen peroxide. Hydrogen peroxide in the UV/oxidation effluent was measured at 46 mg/L. No hydrogen peroxide was added to the system during treatment using activated carbon. The increased toxicity and adverse impacts of the effluent from the UV/oxidation toxicity testing may be due to hydrogen peroxide or copper since these are the only water quality parameters that varied between the two tests.

In toxicity testing it is not uncommon to observe low level adverse impacts such as those observed during testing using effluent from activated carbon treatment. These adverse impacts however may be due to Tolcide in the effluent at levels below the 5 mg/L detection limit. In addition, the toxicity testing procedure uses water from Hampton Harbor, NH rather than New Bedford for an experimental control. It is possible that water from the New Bedford Harbor is naturally more conducive to adverse impacts on the indicator organisms than water from Hampton, NH. It is not believed that the activated carbon process directly imparts any characteristics to the effluent that could be attributed to the increased adverse impacts observed during toxicity testing.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The success of the PDFT was determined by a number of factor's including:

1. The dredge contractor's ability to assemble and operate a current state-of-the-art portable dredge system that improved performance as compared to the prior Pilot Dredging and Hot Spot Dredging events with hydraulic dredge systems.

2. The ability of the PDFT team to conduct extensive data collection and field measurements to evaluate test performance.

Foster Wheeler contracted with dredge contractor BELLC to develop a dredging system that enabled accurate dredging of the contaminated sediment, minimized the amount of water added during the slurry pumping process, and recycled the dredge slurry effluent.

BELLC was successful in designing, fabricating and demonstrating the following key state-of-the-art dredge systems for the PDFT:

- A portable, shallow draft barge platform;
- A mechanical dredging system incorporating a hydraulic excavator with a sealed environmental clamshell bucket of Boskalis Dolman design, capable of a relatively high production rate, and horizontal and vertical dredging accuracy;
- The SPU with discharge pipeline, as a means of providing relatively high and controllable solids concentrations of the dredge slurry;
- A water recirculation system, to demonstrate the practicality of recycling decant water from the Sawyer Street CDF as makeup water for hydraulic dredged material transport; and
- Capabilities for providing continuous dredge production and positioning data, including discharge flow rate, solids concentration, material production, cycle times, and advance rate.

The performance of the dredge system was successful, as summarized in this report.

The PDFT study team, including USACE, EPA, Foster Wheeler, ENSR and other subcontractors were also successful in planning and carrying out field data collection programs for the PDFT.

To evaluate the performance improvements of a state-of-the-art environmental dredge technology over conventional dredge technology previously used at the site several performance areas were evaluated:

- Percent (%) solids concentrations in the dredge slurry and slurry pumping capabilities;
- Horizontal and vertical dredging;
- Dredge production rates in shallow water and sediment with debris;
- Potential impacts to water quality;
- Potential impacts to air quality; and
- Removal of the contaminated sediment to a given depth.

A secondary goal of the PDFT was to evaluate this new technology with regard to site specific cleanup levels. Additional objectives of the PDFT were to evaluate the effectiveness of applying contaminant dispersants and flocculents within the CDF to reduce PCB losses to air from the CDF, to evaluate mechanical dewatering methods for water treatment sludges and to evaluate the use of GAC to treat wastewater.

The PDFT team performed these evaluations. The results are summarized in the report.

6.1 Dredge Performance

Dredge performance testing results as related to the removal and transportation of PCB contaminated sediments during the PDFT are presented in Section 3.0 of this report. The main areas of interest and investigation were in dredge production, dredging accuracy, and dredge slurry solids concentrations and water management. The findings of these investigations are summarized below.

6.1.1 Dredge System Production

Dredge production monitoring was performed over the course of dredging operations in the PDFT test area. Dredging was performed to obtain representative production rates over a range of conditions, including varying depths, bank height, and chemical and physical conditions.

The production performance of the PDFT test dredge, a hybrid system involving mechanical excavation and hydraulic material transport, was based on two main processes: material excavation and materials transportation. These processes, while integrated, were evaluated separately, in order to determine the production limits of the dredge system as a whole. This production evaluation method can be adapted for other dredging processes involving either hydraulic dredging, mechanical dredging with barge transportation and rehandling of dredged material, or other hybrid systems.

Excavator Production

For excavator production, basic dredge production parameters, involving bucket capacity, cycle time, depth of cut, bank height, and dredge shifting (advances) within an anchor set will define the maximum production for a given mechanical dredge. The actual realized dredge production will account for both foreseen and unforeseen delays including re-setting of anchors, mechanical repairs, weather, fueling, operator skill, and other delays. The delays found to be of most consequence with the test dredge excavator production included re-setting of the anchors, downtime due to dredge positioning system repairs, and waiting for the SPU system to be online.

The type of sediment dredged over the course of the PDFT did not appear to impact excavator production one way or the other. In either soft black silt, sand, shell, or clay, the HPG bucket had no problems removing the material. Delays due to material type were encountered on the SPU end of the process as discussed below.

Over the course of the PDFT, the representative average production rate for the excavator was 80 cy/hr. In general, this production was achieved in areas with depth of cut (bank height) ranging between 1.7 ft. and 2.0 ft. On the final day of dredging, August 18, the depth of cut (bank height) was between 3 ft. and 4 ft., and the excavator production averaged 106 cy/hr. Considering that the BELLC dredge system and crew had still not been optimized after only one week of test dredging, SPU suction pressure reduction due to debris blockage had not been fully remedied, and the bucket was only being approximately 75%-80% loaded, it is believed that the excavator production observed over the duration of the PDFT could be increased by 20% on a full scale project in the Upper Harbor to approximately 95 cy/hr. This production range would only be attainable in deeper areas of the harbor where access to the dredge areas was unencumbered by a dredge of similar scale, and draft characteristics to that tested during the PDFT.

In shallower areas, where working of the tides would increase the number of barge movements and reduce the overall dredging efficiency, the dredge production would be anticipated to be significantly less. Alternatively, a smaller dredge with less production capacity than that of a dredge of the scale tested during the PDFT could be used. In either case, with either a larger dredge working the tides, or with use of a smaller dredge, the production range would be on the order of 35 to 50 cy/hr. This is an estimate only, based on knowledge of the anticipated reduction in production efficiency (50%-60%) due to depth restriction on a larger dredge, and an understanding of production capacity of shallow hydraulic dredges. Both the breakpoint at which a larger production environmental dredge would be replaced by a smaller dredge, and the production range of that smaller dredge will be better assessed in the 90% Basis of Design/Design Analysis for the Dredging Design, to be completed in 2001.

SPU Production

The production limit for the BELLC test dredge was found to be on the hydraulic transportation system (SPU) during the PDFT. The production performance of the test dredge was impacted most significantly at the onset and throughout the PDFT by the clogging and blockage of the suction line between the bottom of the material hopper and the primary mover (slurry pump). Here objects consisting primarily of cobbles, metal debris and live quahogs accumulated against the rockbox screen, reducing the suction pressure, and attainable production threshold of the SPU system. Throughout the PDFT the primary focus of optimization was on the hydraulic transport system (SPU). Modifications, which included the addition of water jets in the suction line, baffle walls welded in the hopper, and other operational measures, were made to remedy the production problems encountered due to debris. Only during the last three days of test dredging, August 16, 17, and 18, did the dredge realize running time representative of a full-scale remediation.

Of interest in the SPU production report, for August 17, the most representative testing day for SPU performance, the dredge's efficiency was 77.8% (i.e., *in situ* sediment was dredged during 77.8% of the time dredge operations were ongoing). Dredging efficiency refers to the total actual dredging (effective) time divided by the total operating time (including delays). During this day 2,509 cy of slurry was discharged, of which 537 cy of the slurry was *in situ* sediment moved. The average volume of slurry moved was 346 cy/hr, and an average volume of *in situ* material of 74 cy/hr. It is believed that for the full scale, with optimization of the debris management system, the SPU production will match, or exceed that of the excavator production.

6.1.2 Dredging Accuracy

Key to the success of the New Bedford Harbor full-scale remediation will be the ability of the selected dredge(s) to minimize the amount of overdepth dredging while still attaining the target cleanup goals of the project. The BELLC hydraulic excavator type dredge was selected for pilot testing, in part, to demonstrate that a mechanical bucket operated from an excavator with rigid connections and state-of-the-art positioning could achieve dredging accuracy 6 in. or less in the vertical plane and 24 in. or less in the horizontal plane.

Evaluation of dredging accuracy was carried out based on comparison of the post-dredge survey with the target depths. For dredge Cuts 5, 6, 7 and 8, where accuracy was a focus, 95% of the dredge area was within 6 in. of the target depth. In 90% of the dredge area the average vertical dredging accuracy was most nearly 4 in. Most of the points that deviate more than 6 in. are in the slope area, on the north and south ends of the cut. An approximate 1V:1H slope was excavated by the dredge on either side of the test area, while dredging in an effort to minimize sloughing of adjacent areas into the dredged portions of the PDFT dredge area.

After dredging Cuts 6, 7, 8, and 5, respectively, it was realized in the field that a "clean" clay layer was oftentimes higher in elevation than that shown in contamination characterization plots. Thereafter the field target dredge level in Cuts 2, 3 and 4 changed from one based on the theoretical plan to one based on observation. When the operator encountered clay, as evidenced by deposition on the material hopper grizzly, dredging proceeded no deeper in that grab position. Where the clay layer occurred at more than a few inches from the planned theoretical dredge level, the target level was adjusted within tenths of a foot of the visual observation on the next, adjacent spud or "moonpool" position (1/4 of a dredge cut), in an attempt to minimize the removal of the underlying clay.

This visual observation method of determining dredge depth was applied in Cuts 2, 3 and 4. In these cuts, the depth of cut was reduced from a planned 2 ft. cut, to a 1.7 ft. (Cuts 2,3,4) and 1.8 ft. cut (Cut 4). In these areas, the vertical dredging accuracy decreased to an average of approximately +/- 6 in. from the target. This reduction in accuracy was observed to be a result of interruptions in the CMS display to the operator and personnel communication errors. It is therefore reasonable to assume, for a full scale operation, that with rapid and accurate updating of the dredge guidance system to reflect field changes in the target elevation based on visual observations of the clean clay layer, the dredging accuracy will approach that achieved in the areas where the target depth is pre-programmed into the crane operators display.

6.1.3 PCB Removal Efficiency

The evaluation of the dredge efficiency at PCB removal included two components. The first (primary) goal was to evaluate the dredge's ability to remove contaminated sediment <u>to a given depth horizon</u> relative to the dredging plan. The dredge performance was highly accurate in this regard. Comparison of the target dredge volume with the actual volume dredged yielded an overdredging value of only 16%, with vertical accuracy of +/- 4 in. relative to achieving the intended horizon. Comparison on pre- and post-dredging sediment PCB concentrations revealed that 97% of the PCB mass was removed over the dredged area.

A secondary objective of the PDFT was to evaluate this new dredging technology with regard to site specific cleanup levels. The design included: 1) delineating the 10 ppm PCB concentration horizon within the test area; 2) establishing a dredging plan based on that depth; and 3) assessing the dredge's ability to remove sediment to that depth. It should be understood that the project goal was <u>**not**</u> to leave a final sediment concentration of 10 ppm; this was a field test, <u>**not**</u> a remedial operation. The dredge performed quite well in this regard. The average sediment PCB concentration (upper one foot) was reduced from 857 ppm to 29 ppm over the dredged area. This met the clean up criteria of 50 ppm for the Lower Harbor and approached the criteria of 10 ppm for the Upper Harbor.

During the design phase of this project, it was determined that most sediments within the dredge test area had a high water and silt/clay content. This fact introduced the possibility that some contaminated sediment within or immediately adjacent to the dredge area could be mobilized during the dredging process and potentially re-contaminate the dredged area. Mechanisms that could mobilize the sediments include bucket impact on the bottom, loss through the water column (appears minimal for the hydraulic excavator), anchor wire/spud repositioning, and material sloughing down slope along the sides of a dredged cut. Furthermore, other factors such as tidal currents and meteorological events (e.g., wind) could produce the same effect due to re-suspended contaminated sediments migrating from other areas of the harbor. The sediment characterization program included the collection of surface grabs in addition to cores in an effort to quantify the effects of sediment mobilization.

Based on the visual observations of the upper surface of the post-dredge cores and grab samples and the results of laboratory analyses, some recontamination did occur within the test area. Calculations presented in Appendix J (Section J.5) demonstrate that only a very thin layer of re-deposited, contaminated PCB sediment would be required to increase the concentration within a composited upper one foot (0.3 m) sediment core to greater than 10 ppm. For example, if the sediment adjacent to a clean dredge area has a PCB concentration of 1,000 ppm (as was the case in much of the test area), it would require only a 0.24-inch (0.61cm) layer of newly deposited (post-dredging) contaminated sediment to elevate the average concentration of the upper one foot of clean sediment above 10 ppm.

This thickness of contaminated silty material (only a thin veneer) is consistent with field observations and analytical results from the post-dredge sampling. Based on this information, it appears that the observed post-dredge PCB concentration of 29 ppm (upper one foot composite) can be attributed to deposition of mobilized sediments (either from the dredged area or adjacent areas by sloughing, tidal currents, etc.) rather than inefficient or inaccurate dredging.

In summary, both the sediment removal data (presented in Section 3.0) and PCB data presented in this appendix indicate that this dredging technology is very efficient at contaminated sediment removal. The results indicate that 97% of the PCB mass was removed over the test area, and the remaining sediment concentrations approached the site specific clean up criteria. A similar reduction in sediment concentration was observed for the area dredged to planned depth and the area dredged to depth based on the visual method. The PCB mass remaining after dredging appeared to reside entirely in a thin surface veneer and was attributed to recontamination of the dredged area rather than incomplete removal.

Based on experiences during the PDFT, it was determined that remedial dredging to 10 ppm is possible through the use of modified operational procedures and project design. During full scale operations, development of a dredge plan and sequencing that proceeds from upslope to downslope and with an understanding of the site current (tidal) regime would be made to address some of the recontamination effects due to sloughing. Additionally, dredging operational approaches could be employed during the full scale project including return sweeps, tighter overlap of bucket grabs, and slower retrieval of final bucket grab that would provide for a cleaner bottom surface and reduce sloughing of adjacent areas. As confirmation sampling results became available they would be shared with the dredge contractor and the operator in particular to modify dredging techniques to obtain a bottom that met the cleanup criteria.

6.1.4 Dredge Slurry Solids Concentration

The solids concentration values attained by the Bean dredge were impacted by production delays due to debris. Average sustained solids concentration values recorded by the SPU system over periods of dredging are provided in Table 6-1 below.

Table 6-1
SPU Slurry Solids Concentrations

	16-Aug-00	17-Aug-00	18-Aug-00
Average % Solids by Weight of *In situ* Material	45.00%	52.00%	34.00%
Average % Solids by Weight of Dredge Slurry (3rd Loop)*	15.55%	16.84%	15.39%
Greatest % Solids by Weight of Dredge Slurry (3rd Loop)*	18.94%	20.03%	20.22%

* Represents average sustained % solids concentration over dredging period

The sediment within the PDFT test area had *in situ* specific gravity of 1.26 to 1.41, which corresponds to concentrations of 425 to 668 g/L, wet unit weights of 78.6 to 88.0 pcf (1,260 to 1,410 Kg/m^3), solids by weight of 33.8 to 48.6 percent, and moisture contents of 196 to 110 percent. These values are typical for very soft, silt or clay marine sediments with natural organic material.

Average sustained solids concentration values recorded by the SPU system over sustained dredging periods ranged from 13.3% to 16.3% solids by weight. These concentrations were achieved in dredge areas having *in situ* sediments with average solids concentrations of 32% to 43% solids by weight. This corresponds to volume concentrations in the order of 40% to 50%, by volume. The solids concentration values attained by the BELLC dredge were affected by debris. As debris would become lodged in the hopper, suction line and/or rock box, more water was required to be introduced to the hydraulic slurry transport system by the SPU in order to maintain suction pressure, and in an attempt, through the introduction of water jets to dislodge the debris in the suction. Higher solids concentrations would be attainable with inclusion of a more sophisticated debris separation system on the full-scale project.

Based on the results of the PDFT, an average 15% solids by weight for a solids concentration of dredge slurry could be applied to the full-scale remediation of the Upper Harbor, using the SPU system. The actual solids concentration values will be determined by better definition of *in situ* density, and the type of hydraulic transport (pumping) system used.

6.1.5 Recirculation System

A significant aspect of the PDFT was the successful demonstration of the dredge effluent water recirculation system. The recirculation system essentially created a closed loop system, whereby the only water added to the dredge process was that entrained in the dredge bucket. This water addition amounts to 30% to 40% of the *in situ* volume, and includes both the water contained in the sediment and the water in the bucket voids due to incomplete filling. Water was recycled back to the dredge for use as make up water for the SPU system and as jet water for debris management in the suction line. No water was used from the seachest for makeup water for hydraulic slurry transport.

The recirculation system operated without any significant problems. Only one delay was caused by the recirculation system, when the return water pump lost its prime.

Use of a recirculation system should be included in the design and planning of the full-scale project. In this case, the only additional water that will require treatment is that water entrained in the dredge bucket, which conservatively approximates 40% of the bucket volume. Some additional investigation remains to determine if additional water treatment measures would be necessary for the recirculation water, which could develop concentrated levels of PCBs and/or metals, after extensive recirculation.

6.1.6 Bulking Factor

The *in situ* sediment concentration in the dredge test area ranged from 425 to 668 g/L. In areas where the initial sediment concentration is lower than 500 g/L, the bulking factor would be less than 1.3 and could approach 1.0. This is because the pipeline concentration was approximately the same for all the sediment dredged in the dredge test. The concentration in the disposal cell would be about the same. Therefore, the ratio of *in situ* volume to disposal cell volume would be about 1.0. The bulking factor also decreases when the percentage of sand in the sediment increases. The bulking factor for loose sand and gravel is close to 1.0 because the sand settles quickly and the settling that occurs in a disposal cell is similar to natural settlement that occurs in the Harbor.

6.2 Environmental Monitoring

6.2.1 Water Quality Monitoring

The test dredge's ability to minimize environmental impact to water quality was evaluated by measuring the extent of sediment resuspension and transport, and is summarized in Appendix K.

For test days representing full scale remediation, such as August 16, field measured turbidity showed some spikes in the vicinity of the dredge but generally returned to background levels within 500 ft. down current of the dredge. Total particulate PCB concentrations (with "total" reported as the sum of the 18 NOAA congeners) were elevated in the vicinity of the dredge, but returned to background levels within 500 ft. down current of the dredge. During the other monitoring events, some of the turbidity transects revealed little or no detectable elevation of turbidity down current of the dredge. Greater increases in urbidity were generally traceable to dredge support activities or environmental conditions unrelated to field test operations. Barge movements by the support tug *Miami II* in shallow water for instance were recorded as causing suspended solids concentration of 300 mg/L and particulate and dissolved PCB concentrations of 26 and 2.7 µg/L, respectively, within 50 ft. of the tug (background concentrations of suspended solids were 5 mg/L and total dissolved + particulate PCBs were 0.75 ug/L on this date). Aerial photos, presented in Appendix K and Appendix O, illustrate the visual difference in the turbidity plumes associated with the tug and the dredge.

The limited water column impacts associated specifically with the dredging are attributed to both operational and environmental factors. The design of the bucket (tight closing with limited leakage), the configuration of the dredge (with a "moon-pool" work area enclosed behind a 36-inch silt curtain), and the controlled manner in which the operation was executed all contributed to minimizing the release of material to the water column. The shallowness of the area (maximum depth of the dredged area was less than 10 ft. at high tide) and the limited currents (maximum currents generally less than 0.5 ft./sec) limited transport away from the dredging area.

Difficulties associated with handling and transferring sediments containing debris and large components of embedded shells did cause regular suspensions of dredging operations. However, the periods of continuous dredging were sufficient enough to establish "steady state" conditions in the near field area (within 200 ft. (61 m) of the dredge) and are considered representative of continuous dredging operations. More continuous dredging over a full or multiple tidal cycles would not be expected to generate a turbidity plume of greater extent in the nearfield area down current of the dredge than that observed during the field test. Based on the modeling predictions presented in Section K.2, any additional farfield increases are expected to be limited to the Upper Harbor.

6.2.2 Air Quality Monitoring

Different types of air samples were collected to achieve various objectives during the PDFT. These included the following:

- Flux chamber sampling provided a measure of emissions as an indication of the relative contributions from the various operations to the ambient air concentrations. These will also be used to support the emissions and dispersion modeling calculations performed as part of developing ambient air action levels for upcoming construction work. In addition to flux chamber samples collected in the field, sediment from the bench scale dewatering studies was tested at the USACE WES for emissions measurements. Test results were reported to USACE.
- Ambient air sampling and analysis was performed from locations around the CDF and harbor to document concentrations during operations.
- Sampling was conducted in accordance with the Foster Wheeler TO #17 *Sampling and Analysis Plan* (SAP), Revision #6, dated August 2000 (FWENC, 2000c). The data from these tests are summarized and discussed in the following sections.

Flux Chamber Sampling

In summary, limited flux chamber sampling during the PDFT provided useful data for evaluating relative emissions from various sources. Some key findings are summarized as follows:

- Emission flux measurements do not correlate well with source material concentrations. However, they do generally appear to be the highest in association with well mixed sediment and water slurries in the CDF.
- *In situ* sediments in the mudflat area do not provide the same magnitude of emission flux per square area as well mixed sediment in the CDF. However, given the large surface area of the exposed mudflats at low tide, these areas and exposed surface water will continue to be a significant source of ambient air concentrations of PCBs, as measured during the Baseline study.
- Total emissions, calculated as (flux) x (surface area) x (time), are directly proportional to the amount of exposed surface area. Accordingly, exposed CDF surface area is a significantly greater source of emissions than dredging operations. The contaminated sediments in the mudflat areas and the river/harbor surface water remain the largest surface area sources of emissions.
- Dredging activities, including the grizzly, hopper, and disturbed sediments in the moon pool are relatively small sources of PCB emissions in comparison with the CDF because of their lower flux measurements and limited surface area.
- The use of surfactants Dawn and Biosolve to control the sheen at the CDF does not appear to be effective at controlling PCB emissions. These limited data suggest that Simple Green may be more effective than other surfactants although additional testing is recommended before drawing definitive conclusions.
- The silt curtain at the moon pool appears to be somewhat effective at containing disturbed sediment thereby reducing the surface area of higher concentration water and the associated emissions in the dredge area.

Ambient Air Sampling

Ambient air samples were collected on three days during this PDFT to document conditions during dredging and CDF filling operations. Because of the short duration of the test, and the fact that PCB health effects are long-term, data were collected to document conditions and to provide information for full-scale activities at a later date. Data were not used to compare with standards or action levels for this limited one-week effort. The results from this study will be used in conjunction with the flux chamber results (discussed above) to support development of ambient air action levels, being conducted by Foster Wheeler under a separate task.

Ambient air samples were collected from four stations around Cell #1 (2, 3, 6, and 17), from station #9, located to the north across the cove from the CDF, and from station #27 on the eastern side of the harbor near the dredge. Figure 4-4 shows the air sampling station locations. Samples were collected for 24 hours on each of three days (sampling was started the mornings of August 15, 16, and 17, 2000) chosen based on those days with maximum dredge production rates and warm weather as representative of “worst case” conditions. Samples were analyzed for NOAA and WHO congeners and total PCB homologue groups. Meteorological data and sample results are included in Appendix L and summarized in Table 4-2.

The highest total PCB concentration detected was at station #17 (610 ng/m^3), the station downwind from the CDF on August 15. Stations 3 and 6 also had detected concentrations above 100 ng/m^3 on August 15, 2000. High concentrations on other days ranged from 100 (as measured by the Foster Wheeler primary laboratory, 254 measured by the government QA laboratory) to 160 ng/m^3 at stations 3 and 2, respectively, with somewhat elevated concentrations ranging from 82 to 110 ng/m^3 at stations 2, 3, 6 and 17 on August 16 and 17. Results from stations 9 and 27, away from the CDF, had lower concentrations (less than 50 ng/m^3 on each day) and were also dependent on wind direction. These data support the premise that, other than background attributed to the mudflats and surface water, the primary sources of PCB concentrations in ambient air are due to emissions from CDF operations. Results from station 27 indicate that ambient concentrations were generally consistent with established baseline concentrations for the Acushnet Substation (summer and September 2000 averages ranged from 20 to 40 ng/m^3) (Foster Wheeler *Final Annual Report Baseline Ambient Air Sampling and Analysis*, March 2001) and were not significantly adversely affected by dredging operations.

6.3 Comparison with Pilot Dredging and Hot Spot Dredging Events

The Foster Wheeler report *New Bedford Harbor Cleanup, Dredge Technology Review* (FWENC, 1999), developed to assess applicable dredge technology for implementation of the New Bedford Harbor full scale remediation concluded that dredging technology used for environmental remediation dredging had changed substantially since completion of both the New Bedford Harbor Pilot Dredging Study in 1989 and the Hot Spot Dredging event in 1995. The dredge technology showing the best performance on these events was the Ellicott 370 HP Dragon Series 10-inch (discharge) hydraulic cutterhead dredge. This dredge therefore established the baseline for the Upper harbor site in terms of dredge efficiency and performance. Prior studies had excluded mechanical dredging techniques for use on these two events due primarily to the inefficiency of barge transport to the disposal facility because of shallow operating depths, the perception that a hydraulic system left a more uniform bottom surface and concern over resuspension of contaminated sediments.

Table 6-2 compares the key performance areas evaluated during the Pilot Dredging, Hot Spot Dredging and PDFT events.

Each of the three dredging performance evaluations summarized in Table 6-2 were conducted across different test areas with different chemical and physical conditions and with different performance testing/cleanup objectives. The PDFT, however, has demonstrated that current state-of-the-art dredge technology, in particular a hybrid mechanical/hydraulic dredge with sophisticated environmental controls systems, can attain dredge performance values exceeding that of the baseline dredge, the Ellicott 370 HP, particularly in the areas of dredging accuracy, dredging production, and solids concentration of the dredge slurry.

6.4 Recommendations for Full Scale Remediation

The PDFT was conducted to provide optimum, site specific dredge performance values for use in developing the New Bedford Harbor full scale remediation project. To provide the most realistic data for use in development of the full scale remediation project, the PDFT was conducted in areas and with equipment that would be reflective of the full scale project, to the extent possible.

The PDFT successfully demonstrated and recorded performance data including dredge production, accuracy, slurry solids concentration, air and water quality impacts, reflective of dredge technology currently available in the U.S. dredge industry.

Table 6-2
Dredging Performance Comparison

Performance Data	Pilot Dredging Study [1] Ellicott 370 Dragon Series	Hot Spot Dredging [2] Ellicott 370 Dragon Series	Pre-Design Field Test BELLC Hybrid Test Dredge
Total Available Work Days	N/A	345	10
Total Dredge Days	8	261	5
Total Shutdown Days [3]	N/A	32	0
Other Non-dredge Days	N/A	52	5
Total Quantity Removed (cy)	951	14,000	2,308
Required Quantity (cy)	1,574	8,428	1,985
Overdredge Quantity (cy)	0	5,568	323
Overdredge Percentage	0%	66.10%	16.30%
Number of passes	1	2	1
Area Dredged (sq. ft.)	21,250	189,742	24,900
Area Re-Dredged (sq. ft.) [4]	0	22,760	0
Avg. Dredge Time (hrs/day, pay)	4.1	7.7	11
Avg. Dredge Time (hrs/day, prod.)	3.2	4	5.2
Average Production Rate (cy/hr) [5]	37	13.4	72.5
Effective Time	78%	52%	47%
Target depth of cut	2 ft.		1.7 to 4.0 ft.
Accuracy	average underdredge by 9.5 in.	N/A	+/- 4 in.
Solids Concentration of Dredged Slurry (by weight)	2-3%	2-3%	13-16% using patented SPU. Recirculation system was also adapted to test dredge permitting the reduction of water to be treated by an estimated 300% over conventional hydraulic slurry pump capabilities.
Water Quality Impacts	Sediment Resuspension Rate at the point of dredging was estimated to be 40 grams per second.	60 Kg PCBs migrated from Upper Harbor to Lower Harbor over 18 month duration of project. Well within the 240 Kg mass cumulative transport non-exceedance level.	PCB concentrations elevated near dredge, but returned to background levels within 500 ft. down current of dredge. Larger increases in turbidity were generally traceable to dredge support activities or environmental conditions. Barge movements by tug in shallow water were recorded as causing suspended solids concentration of 300 mg/L and particulate and dissolved PCB concentrations of 26 and 2.7 µg/L within 50 ft. of the tug.

Table 6-2
Dredging Performance Comparison – *Continued*

Performance Data	Pilot Dredging Study [1] Ellicott 370 Dragon Series	Hot Spot Dredging [2] Ellicott 370 Dragon Series	Pre-Design Field Test BELLC Hybrid Test Dredge
Air Sampling	N/A	Demonstrated that disposal of contaminated sediment into the shoreline CDF raised ambient PCB levels above background, but not to the point where worker safety or public heath threatened.	Over 24 hrs of ambient air sampling the highest total PCB concentration detected (610 ng/m^3) was downwind from the CDF. High concentrations on other days ranged from 50 to 160 ng/m^3 and were dependent on wind direction. These data support the premise that, other than background attributed to the mudflats and surface water, the primary sources of PCB concentrations in ambient air are due to emissions from CDF operations.

[1] During the Pilot Scale Study, the Ellicott 370 was tested in 5 separate dredge areas, each with different operational parameters and sediment types. Dredge performance values for the area most representative of the Upper Harbor condition, Area 1, are presented for comparison here. The Ellicott 370 was operated at 40% swing speed, 50% maximum cutterhead rotation, and 100% pump speed. Only one pass was performed in Area 1. (USACE, 1990)

[2] During the Hot Spot Dredging, the Ellicott 370 was used to remove sediment with the highest PCB concentrations in the Harbor. Multiple passes and confirmation sampling were necessary to ensure the 4,000 ppm cleanup level was attained. The dredge capacity (advance rate and cutterhead rotation) was kept at close to 50% to minimize environmental impacts due to the dredging operations. (USACE, 1996)

[3] Shutdown Days represent dredge days shutdown by Owner (USACE)

[4] Area Re-Dredged represents dredge area where more than one pass was made

[5] Based on average over all dredge days

Table 6-3 presents the recommended dredge performance values for use in designing the New Bedford Harbor Full Scale Remediation Project, based on the data obtained over the course of the PDFT.

Table 6-3
Recommended Dredge Performance Values for Use in Designing the New Bedford Harbor Full Scale Remediation

Dredge Performance Parameter	Recommended Design Value
Dredging Production, Water Depths greater than 4 ft. [1]	95 cy/hr
Dredging Production, Water Depths between 2 ft. and 4 ft. [1,2]	35 cy/hr
Dredging Accuracy, Vertical Plane, to Design Depth	+/- .4 ft.
Dredging Accuracy, Vertical Plane, using Visual Approach	+/- .5 ft.
Dredging Accuracy, Horizontal	+/- 1.5 ft.
Average Solids Concentration of Dredge Slurry [2]	10% - 20% solids by weight
Use of Recirculation System for reuse of Dredge Effluent Water from CDF	Recommended

[1] Based on minimum of 10 hr. operating day
[2] To be better assessed in the 90% Basis of Design/Design Analysis
[3] Will vary depending on *in situ* density of dredged sediment

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